CEP
CHEMICAL ENGINEERING PROGRESS

FEBRUARY 1959

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Part One

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CEP

CHEMICAL ENGINEERING PROGRESS

February 1959 Volume 55, No. 2

Published monthly by American Institute of Chemical Engineers. Editorial and Advertising Offices, 25 West 45th Street, New York 36, N. Y. Communications should be sent to the Editor. Statements and opinions in *Chemical Engineering Progress* are those of the contributors, and the American Institute of Chemical Engineers assumes no responsibility for them. Subscriptions: U. S. and possessions, one year $6.00; two years $10.00 (Applies to U. S. and possessions only). Canada, $6.50; Pan American Union, $7.50; Other Foreign $8.00. Single copies of *Chemical Engineering Progress* older than one year cost $1.00 a copy; others are 75 cents. Second class mailing privileges authorized at New York, New York. Member of Audit Bureau of Circulations. *Chemical Engineering Progress* is indexed regularly by Engineering Index, Inc.

Cover by *Paul Arlt.*

◄ For more information, circle No. 13

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CEP .... in this issue

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noted and quoted

Research in Engineering

A. B. Kinzel, *Vice-President, Research, Union Carbide Corp.*

You have all heard the statement that for every dollar spent on research in a single given project, ten dollars are spent in development and engineering, and 100 in building the plant. Now what this means is that the amount of effort that is put on a given project after it has passed to a so called successful research stage is at least that much more. It is tenfold. And this is primarily the job of the engineer. There is a gray area, of course, which we call development, where research and engineering must work hand in hand and in this gray area we find need for research not only in the Chemistry, but primarily in the engineering itself. Why does it cost ten times as much to do the engineering part of the job? Well, the main reason, of course, is that the magnitude is much greater, the scale is much greater. You are operating not in grams, but in pounds or possibly tons, and this in itself brings about the factor. But there is more to it than that, because you have ancillary problems, for example, matters of safety. In carrying out research safety is important and certain precautions are taken but they don't cost very much. Now the minute you start to go into a pilot operation or a development stage where the quantities involved are very much greater, you have a whole new series of problems that you must face which have to do with safety, and this contributes to the cost. . .

We have all heard the statement, unfortunately true by and large, that it takes seven years to go from the test tube to the tank car. Now why? This time is taken in first evaluating a project, in constructing—designing and constructing pilot plants, in testing the markets, in building the plant after the economic decision has been made by the financial people involved and then finally building up applications to a point where you have tank car consumption. We all want to speed this up because it is a very expensive operation. If you figure that you get six per cent on your money or possibly eight or possibly ten depending upon a number of things; the time lag is very expensive. We all

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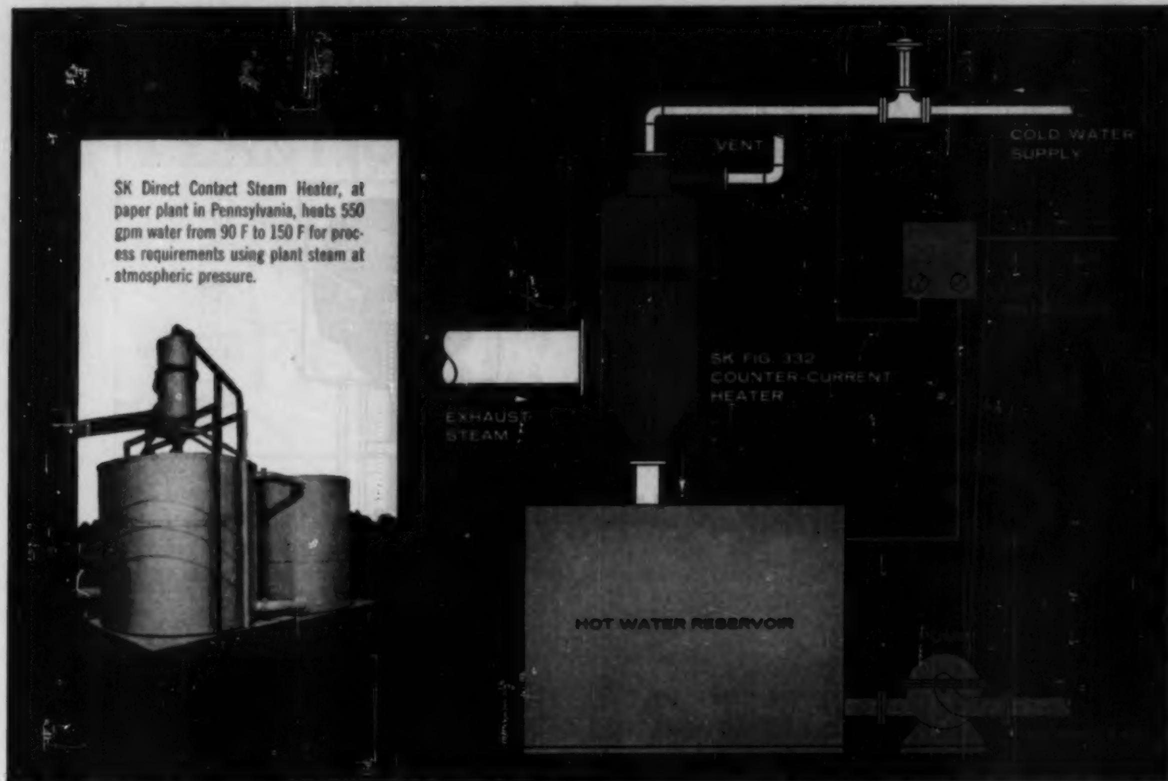
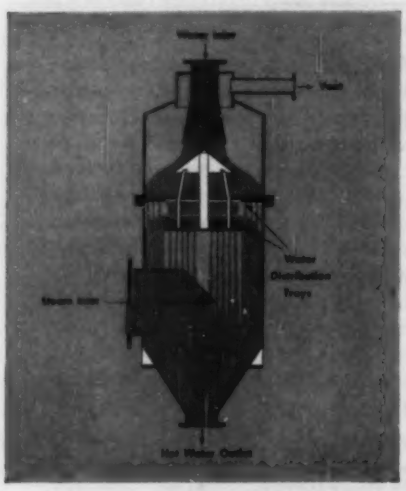


SK Direct Contact Steam Heater, at paper plant in Pennsylvania, heats 550 gpm water from 90 F to 150 F for process requirements using plant steam at atmospheric pressure.

FOR HOT WATER IN LARGE QUANTITIES

use SK Direct Contact Steam Heaters

Sectional drawing of SK Fig. 332
Direct Contact, High Capacity, Steam Heater



SK Direct Contact Steam Heaters are designed to provide large quantities of hot water, or other liquid, for plant or process use. They do this by using plant exhaust steam (at low pressure or at vacuum to 15 in. Hg) to heat the water which is then delivered to a tank or reservoir.

To users, these high capacity heaters offer specific, worthwhile advantages. They are simple in design, have no moving parts. Heating, by condensation of steam in the liquid, is very efficient, continuous, and fast. A temperature rise of 130 F is possible with most of these units. Semi-solids in the liquid are handled without difficulty. Costs are reasonable and the heaters require little maintenance. Capacity can be just about any reasonable amount desired, since capacity is determined by heater size and SK has not established any maximum. Although cast iron and fabricated steel are standard materials of construction, other special materials can be used when required.

The counter-current unit pictured above and at left is one of four types made by SK. This particular heater and all of the other types are described in detail in Bulletin 3A-HC which includes application information and data on sizes, dimensions, and capacities. Copies of Bulletin 3A-HC are available immediately on request. Send for a copy.

JET APPARATUS: Ask for Condensed Bulletin J-1.
ROTAMETERS & FLOW INDICATORS: Ask for Condensed Bulletin M-1.
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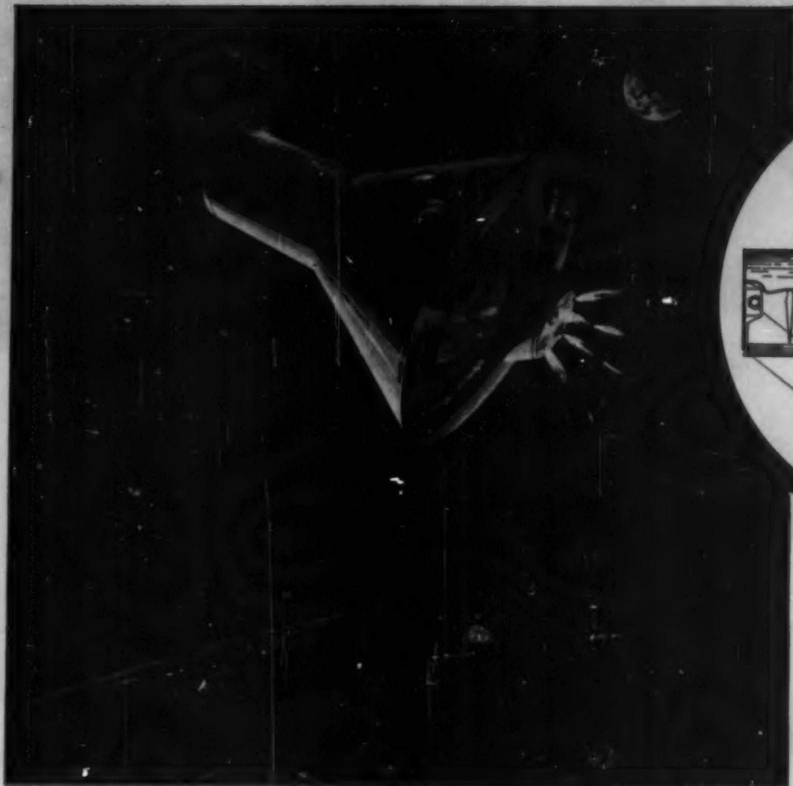

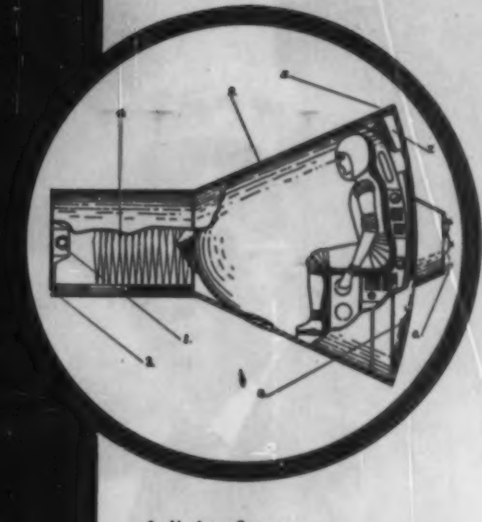

1. Horizon Scanner
2. Entrance Hatch
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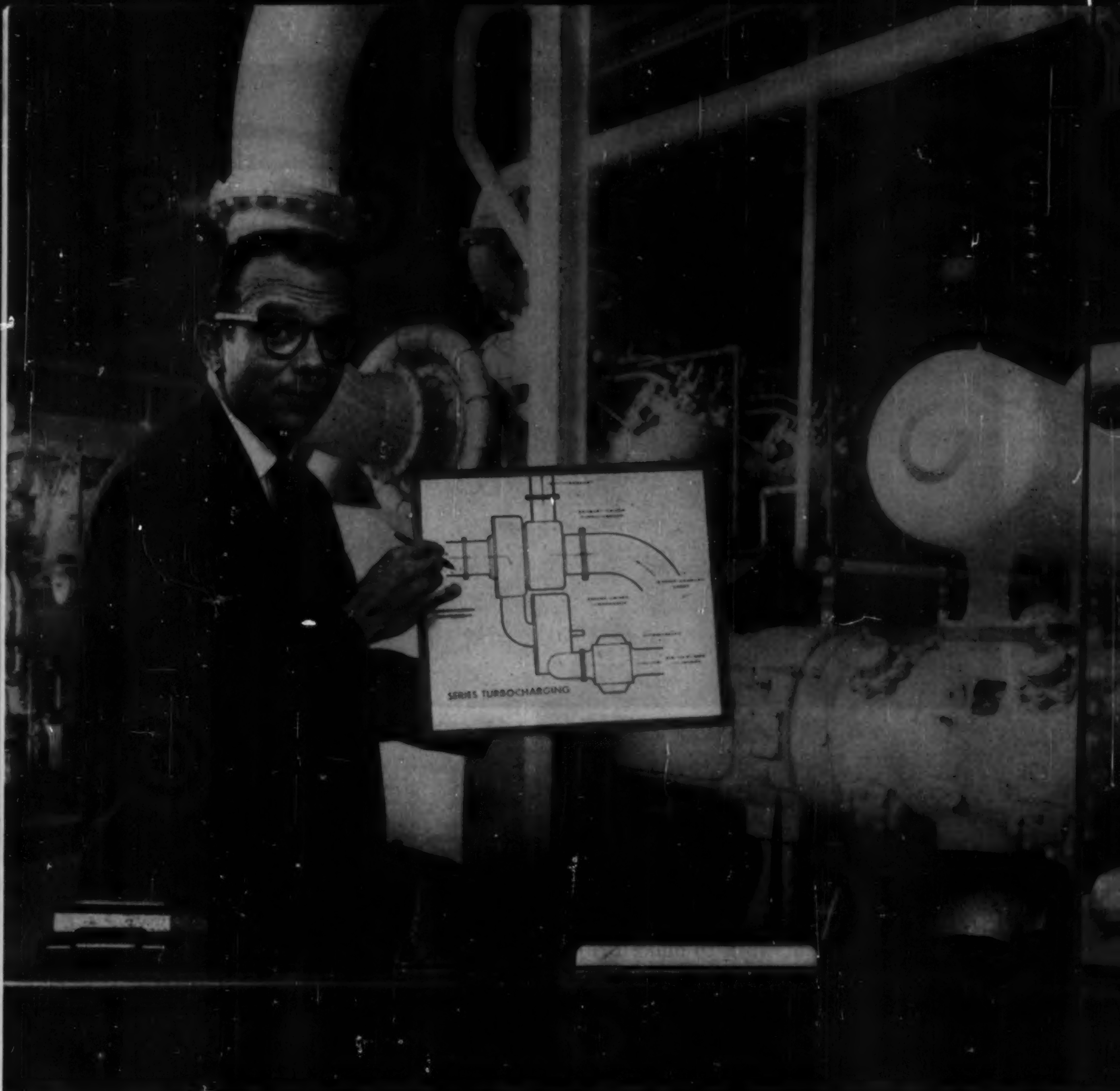
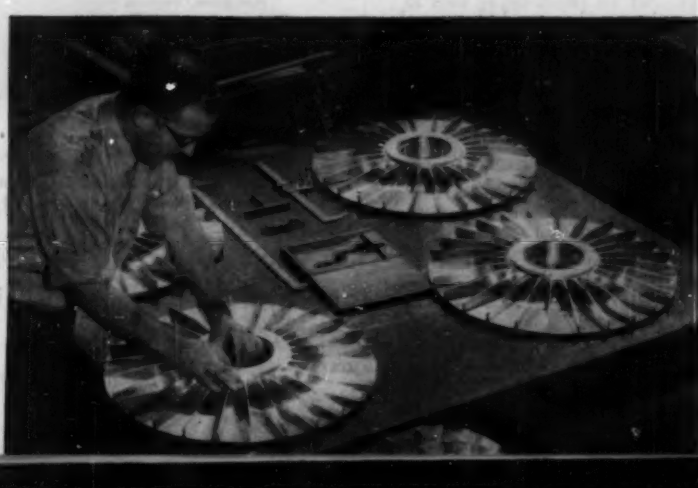
NASA National Aeronautics and Space Administration





Built Entirely By Cooper-Bessemer. Cooper-Bessemer is able to ideally integrate turbocharger system and compressor engine performance . . . and to assure highest standards of materials and workmanship for these precision components.

Donald L. Reed, *Manager Gas Engine Compressor Sales, The Cooper-Bessemer Corporation, explains . . .*

How you get 40% more power with the latest Cooper-Bessemer V-Angle Compressors

The diagram explains Cooper-Bessemer's series turbocharging development. A step beyond ordinary turbocharging, *series turbocharging* assures an extra performance margin throughout the operating range, plus these unmatched advantages:

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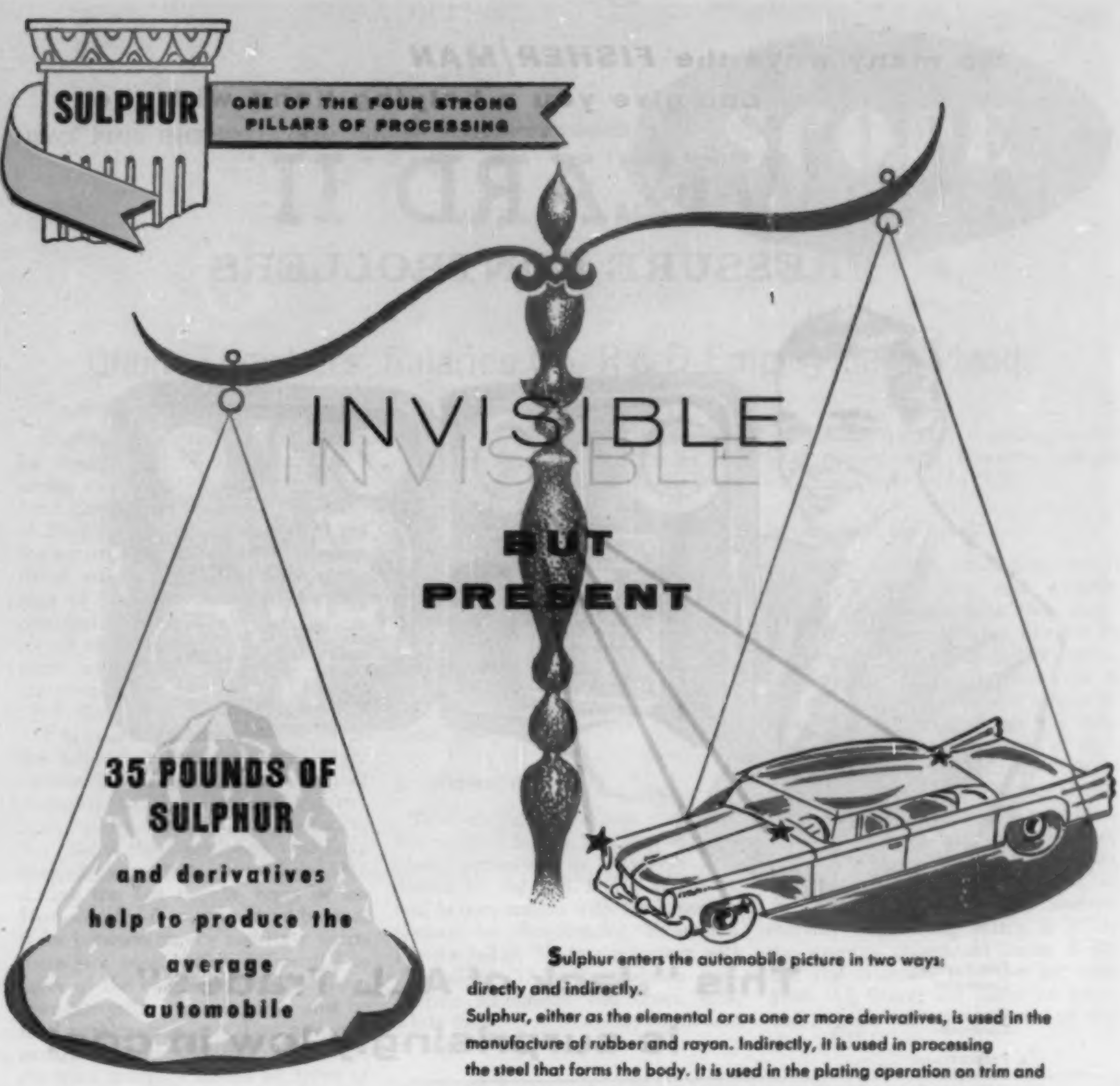
want to do what we can to speed this up so we ask the question, "Why does it take so much engineering when we have such good chemical engineering knowledge?" We have our unit operations. After all these unit operations are well worked out. We know a lot about them. And it shouldn't be necessary to re-engineer every single project that comes along. Well, gentlemen, I give you the fact that we don't know very much about our unit operations. . .

Not so long ago our Electro Metallurgical Division was interested in filtering the ash out of pitch. Filtration is a standard unit operation and there should have been nothing to it. I can assure you that it took a lot of hard research, design, and exploration before we finally got that one under our belt. And why is it that we know so little? What's the problem? Well, it is just this. That whenever you come along with a new product or new process you have a new material. This new material reacts differently to changes in environment. And when it does, the unit operation is affected and we don't know really enough about how and why. . .

The engineers by and large have done a magnificent job. They have done this job on the basis of some knowledge and a great deal of experience. There are some notable exceptions, and if you want to know who they are, look at the balance sheets and profit statements. But the chemical industry as a whole has not done very much in the way of research in engineering. By and large it is done in connection with a given project, and the immediate need to know. But basic information, basic engineering and engineering research which could be available before we needed it, would certainly go a long way towards cutting down this seven year interval that we are all concerned about. The chemical industry in general has been too prone to let the manufacturers of equipment do this sort of thing. These people have done it fairly well, but only within the limits of their own interests. One cannot criticize them for this. . .

I give you a plea that you do engineering, and look upon engineering, just as we look upon applied research and chemistry. There are applied jobs to be done. We get there faster, oftener, and more profitably by doing a certain amount of basic research.

Given at the American Institute of Chemical Engineers Jubilee Meeting, Philadelphia, Pa.



Sulphur enters the automobile picture in two ways: directly and indirectly.

Sulphur, either as the elemental or as one or more derivatives, is used in the manufacture of rubber and rayon. Indirectly, it is used in processing the steel that forms the body. It is used in the plating operation on trim and fixtures. It is deliberately introduced into certain steels to provide better machining qualities.

Recognizing the importance of Sulphur to the basic industries such as the manufacture of automobiles, and to our ever-expanding economy generally, TGS is broadening its service: production, distribution and technical.

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Chem Engineers' Salaries Up, R & D Employment Steady

Chemical engineers will find food for thought in the further results of a survey recently released by Engineers Joint Council on Professional Income of Engineers. Tabulated herewith are the survey figures on median earnings for all engineers against median earnings of engineers employed in the chemical industry. (Advance figures for all engineers, in industry, government, and engineering college teachers were given in CEP for January, 1958, Scope, page 21).

It is evident from a consideration of the table that there are only slight variations in the median earnings of engineers in the chemical industry from the figures for all engineers, in the case of those engineers who have entered into their professional life during the last twenty years or so. However, for those who have been at it for between twenty and forty years, there is a considerable differential in favor of the chemical industry. However interesting, these figures must be used with caution in making any generalizations. In the first place, the chemical category covers all types of engineers employed in the chemical production field; no attempt was made, for instance, to obtain figures for chemical engineers alone. In the second place, those chemical engineers employed by design and construction firms were included in a design service and construction category, and were thus automatically excluded from the chemical category.

R & D Steady

Engineers in R & D in the chemical and allied industries increased in number only slightly (0.9%) from 1954 to 1957, according to a preliminary report on Scientists and Engineers in American Industry just released by the National Science Foundation. In the field of petroleum products and extraction, however, there were 12% more R & D engineers in 1957 than in 1954. At the same time, increases in the total number of engineers employed in all capacities over the same period were 21.4% for chemicals and 17.5% for the petroleum industry.

NSF survey figures also show that total employment of engineers and scientists in American industry rose by about 30% from '54 to '57 to a record peak of 738,000 in '57. Engineers (in all industries) kept pace, with a rise of about 27%, to a '57 total of 528,000—the largest occupational group.

Enrollment down

Total engineering college enrollment has declined for the first time in seven years, according to a survey conducted by the U.S. Office of Education in cooperation with the American Society for Engineering Education. For the fall of '58, in comparison with the fall of '57, undergraduate engineering enrollment was down 4.5%, while the drop in freshman enrollment in engineering was particularly sharp —11.1%. By contrast, according to the joint survey, total first-time college enrollment was up by 7.0%

Which pays the most?

Ten years after graduation, salesmen and accountants earn a little higher monthly paycheck than engineers, says Frank Endicott, director of placement at Northwestern University. Endicott's conclusion is based on a survey of 205 business and industrial firms, just published under the title of Trends in the Employment of College and University Graduates in Business and Industry (1959 Annual Report). Endicott's figures indicate that, although starting salaries today are generally higher for engineers than for sales or accounting graduates, at the end of ten years, the average monthly engineering salary is $778, the average accountant earns $783, and the salesman tops the list with $866. All figures are based on information supplied on graduates of the class of 1948.

1958 Median Earnings for Engineering Graduates by Year of Entry in Profession, According to EJC Survey.

Year	All Engineers	Chemical Industry
1958	$5,850	$6,075
1957	6,125	6,075
1956	6,475	6,375
1955	6,800	6,675
1954	7,000	6,950
1953	7,400	7,475
1952	7,700	7,700
1951	8,050	8,150
1950	8,350	8,500
1949	8,700	9,075
1947-48	9,200	9,675
1945-46	9,450	9,825
1940-44	10,250	11,175
1935-39	10,825	12,700
1930-34	10,675	13,000
1925-29	10,050	13,900
1920-24	11,200	13,450
1915-19	10,675	14,200

SCOPE

R & D, Science Education Quotas Up in New Budget

"For the fiscal year 1960, research and development expenditures will be increased still further with emphasis on space exploration, peaceful uses of atomic energy, and basic science," says President Eisenhower's budget message just submitted to the new Congress. In cold cash, this means: Department of Defense R & D outlay for 1960 is estimated at $3,692 million, compared with $3,282 million in 1959, and $2,314 million in 1958. AEC funds for R & D in 1960 are budgeted at $846 million (up from $790 million in 1959 and $637 million in 1958). The National Science Foundation is authorized to spend $80 million for R & D in 1960 against $60 million in 1959 and $35 million in 1958.

Outlays by AEC in fiscal 1960 are expected to reach an all-time high of $2.7 billion. Programs for development of nuclear reactors for military and power applications will be continued, according to the budget statement, "at or above the high levels already attained." Promising technical approaches to civilian power reactors will be pursued energetically, as well as efforts to reduce the cost of the reactor fuel cycle. Also provided for is construction, development, modification and operation of experimental and prototype power reactors owned by the Government, including the Shippingport atomic power plant. Finally, there is promised "substantial support of power reactor projects undertaken by groups outside of the AEC."

Increased exchange of technical information with foreign countries is proposed, principally through participation in Euratom and the International Atomic Energy Agency.

Further investigation is promised into the possible use of nuclear explosions for such peaceful purposes as mining and earth moving. (Production of oil from shale oil deposits is also a distinct possibility (see item right.)

Also in the budget is provision for "a higher level of research in the physical sciences," including advanced experimental devices to explore the control of thermonuclear reactions.

Expenditures for the program of research grants by the National Science Foundation are expected to reach $80 million, an increase of $20 million over 1959. For all agencies combined, it is estimated that Federal expenditures for basic research will be about $500 million in 1960. The science education program of the National Science Foundation is estimated at $60 million for fiscal 1960, an increase of $9 million over the 1959 level, and four times the amount spent in 1958.

Washington Notes

A too-little publicized Labor and Science Conference held in Washington last month under the auspices of the Industrial Union Department, AFL-CIO, heard members of a panel on the needs of scientific and professional workers call for an intensive drive to organize engineers, starting with penetration of the engineering school campus . . . A newly-appointed 19-member Science Information Council will serve as consultant to the National Science Foundation's Science Information Service . . . Mandatory acquisition by the government of all rights growing out of research and development contract has been proposed in a report released by the Senate Small Business Committee. If adopted, this policy should make it possible to assign a larger percentage of production contracts to small business. . . A new semi-monthly abstract journal, Technical Translations, is now being published by the Office of Technical Services, Dept. of Commerce.

J. L. GILLMAN, JR.

CPI tab for air pollution control-$1/4 billion annually

The nation's chemical companies alone spend a quarter billion dollars anually for control and avoidance of air pollution, said Gen. John E. Hull (ret.), president of MCA, speaking at the recent National Conference on Air Pollution Control in Washington.

Government, Oil Industry weigh nuclear shale oil project

Based on promising results from a demonstration nuclear explosion in September, 1957, at the Nevada Test Site, Bureau of Mines experts and oil industry bigwigs sat around a table recently in Dallas to discuss ways and means of financing a full-scale "shot" aimed at production of oil from shale oil deposits. Cost for a 10-kiloton blast is estimated at about $2.2 million, $1 million of which would go for preparation and firing of the nuclear device. Reportedly, AEC is asking that industry foot half of the bill, oil companies are reluctant to go ahead without data from an explosion in actual shale oil formations. (The 1957 test was carried out in volcanic "tuff").

SCOPE

Auto Exhaust Afterburners — Mass Catalyst Market?

The auto industry's search for an effective and economic catalytic converter system, spearheaded by Ford and General Motors, has come up with two devices, disclosed at the recent Detroit meeting of the Society of Automotive Engineers. (Perhaps somewhat prematurely, Los Angeles city fathers are reported already drafting legal measures requiring installation of such devices on all new cars in the area by 1961 or 1962).

In "smog-chamber" tests, the Ford device, using a vanadium pentoxide catalyst, is said to have reduced hydrocarbon concentrations by 88 and 91% for idle and deceleration conditions respectively, and by 68 and 74% for acceleration and cruise conditions. In tests regulated to simulate typical Los Angeles car operation, an over-all efficiency of from 60 to 75% is claimed.

From 25 to 30 pounds of catalyst pellets coated with vanadium pentoxide (10% by weight) would be needed with each Ford-type converter, an impressive amount of vanadium compared to today's production levels. Ford estimates catalyst life for the present device at about 10,000 to 12,000 miles, has hopes that a life of 15,000 to 20,000 miles can be attained. Cost of the gadget would be "approximately $150, installed" say Ford officials privately, with some chance of cost reduction on a mass production basis.

An "oxidation" catalyst, developed by Eugene Houdry and made by Oxy-Catalyst, is the heart of a seemingly similar after-burner now the object of a "major engineering developing and testing program" at General Motors. The undisclosed catalyst is reported to perform better than vanadium pentoxide on gasolines containing lead, and to have a useful life of about 12,000 miles.

Third candidate in the race is a non-catalytic afterburner developed by Ramo-Wooldridge. No catalyst is involved, only requirement is a supply of oxygen. Main difficulty standing in the way of cheap, efficient application is said to be the problem of handling the high temperatures developed. No figures have been released on the probable cost of the Ramo-Wooldridge device.

Implications of construction contracts

A methanol plant built by M. W. Kellogg for Monsanto and Heyden Newport Chemical in Texas City is the subject of litigation which, because of disagreements, has reached the stage where Kellogg is attempting to force arbitration under the provisions of the construction contract. At stake in the controversy is about $9.5 million as damages, claimed by Monsanto in a separate suit against Kellogg, a sum which exceeds the entire cost of the plant in question (about $6.5 million). Monsanto charges that Kellogg's original claim to have sufficient knowhow to build the plant was unfounded. Part of the knowhow for the plant was obtained by Kellogg from Imperial Chemical Industries (England) and Linde Gesellschaft (Germany). Kellogg counters that, "months before the final contract was drawn," Monsanto was fully informed of the outside sources of the technical data. Kellogg further charges that by "putting a technical construction of fraud" on the matter of outside procurement of knowhow, Monsanto is seeking to disregard the arbitration provisions of the contract. Original startup date for the plant was to have been November, 1954. For a variety of reasons, a successful test run was not completed until June, 1957. Main difficulties are reported by Kellogg to have been encountered in initial operation of the Linde low-temperature Saachse by-product gas purification unit, including one limited explosion, attributed to acetylene accumulation resulting from a valve having been mistakenly left open. This resulted in the installation by Kellogg of additional equipment to hydrogenate all traces of acetylene in the raw gas. Another difficulty was encountered with the capacity of the low-temperature regenerators. This, Kellogg reports, led to changes (in 1956) to increase their capacity. This is understood to have been accomplished by changing the packing in these pebble-type exchangers. Other difficulties, according to Kellogg, were occasioned by Monsanto's failure or inability to supply raw gas at the specified rate and composition. At one point, an unrelated explosion in Monsanto's air-separation plant is said to have been partly responsible for the failure.

Two-year technical institutes seen in vital role

"One of the most productive ways to increase our effective supply of professional scientists and engineers is through integrated development of engineering technicians," according to G. Ross Henninger of the American Society for Engineering Education. An ASEE report, slated for early publication, is expected to call for a substantial increase in this type of education.

Prepared by U. S. Industrial Chemicals Co.

U.S.I. CHEMICAL NEWS

Feb. ★ A Series for Chemists and Executives of the Solvents and Chemical Consuming Industries ★ 1959

Polyethylene Properties Of Great Value to Labs Handling Radioisotopes

Polyethylene's properties of radiation-resistance, chemical inertness and physical toughness are proving invaluable to a fast-growing group of chemists and engineers who work with radioactive isotopes in the laboratory.

Contamination—its prevention and elimination—is of course the greatest concern of those who work with radioactive materials. Polyethylene reduces the problem in a number of ways. It is nonionic—will not pick up or transmit stray ions readily. It is nonporous and chemically inert—so can be cleaned easily. Polyethylene containers, equipment and furnishings are generally one-piece moldings—eliminating cracks and joints which might trap radioactive particles.

A highly radiation-resistant material, polyethylene can take doses up to six megaroentgens without degradation. In fact, low doses of radiation have been used to improve the heat resistance of this plastic. Polyethylene has even been employed as a secondary shielding for neutrons which penetrate lead.

Polyethylene makers are looking forward to a fast-growing market for their products in the lab—and perhaps even in the plant—as radioactive materials become increasingly available for industrial use.

New Safety Data Sheet Out on Phosphoric Acid

Properties and safe-handling practices for phosphoric acid have been compiled in a new safety reference booklet now available from MCA at nominal cost. The 14-page booklet covers hazards and their control, employee safety, fire fighting, handling and storage, equipment cleaning and repairing, waste disposal, health measures and first aid.

As a producer of wet process phosphoric acid, U.S.I. can supply further data on individual safety requirements for specific uses.

Zirconium Valve Stems Prove Ideal for Acid Service at Mallory-Sharon

After 14 months in acid service, 40 zirconium-stemmed control valves are still operating without a single stem failure at the Mallory-Sharon zirconium plant, Ashtabula, Ohio.

The valves are used in all concentrations of hydrochloric and sulfuric acids, raffinate, acidified hexone, solutions of ammonium thiocyanate and thiocyanic acid, and other solutions. Mallory-Sharon engineers say they have proved excellent in every way—requiring very little maintenance or operator attention.

Designed by an instrument engineer at U.S.I. (one-third owner of Mallory-Sharon Metals), the valves were custom-fabricated

MORE

Finely-Divided Sodium Lowers Costs, Improves Yields in Broad Range of Chemical Reactions

Many New Products, New Processes Made Possible Through Development of Finely-Divided Sodium Techniques.

Sodium in the form of dispersions is offering important advantages in many chemical processes today. It provides a reliable mechanism for controlling reaction speed. It makes possible the addition of immediately available sodium at a desired rate, thereby giving better control of reaction conditions. Many chemicals can now be produced in larger yields, in shorter time and at lower cost than has been possible with other materials or other methods.

Dispersions for Claisen Condensation

In Claisen condensation reactions, sodium dispersions give high yields and fast reaction rates in the production of such compounds as ethylacetoacetate, ethylbenzoylacetate and ethylsodiumoxalacetate. In the condensation of ethylacetate to ethylacetoacetate, for example, a combination of highly dispersed sodium and increased temperature gives practically quantitative yields of acetoacetic ester, based on sodium. The use of this technique eliminates the time-consuming preparation of sodium ethylate.

Organosodium Compounds

Finely-divided sodium now offers a simple, economical route to many old and new compounds of the organosodium type (containing direct carbon-to-sodium bond). These compounds are obtained by halogen replacement, hydrogen substitution or addition.

Using halogen replacement,

MORE

Commercial reactions using sodium dispersions are run in conventional equipment like this jacketed kettle.

Use of Chemical Milling Grows in Metalworking

Many metalworkers are now using chemicals to etch out complex metal shapes to very close tolerances. Large amounts of metal over wide areas, to a depth of about one inch maximum, can be removed economically by this technique on jobs where conventional machining operations would be difficult and costly, or sometimes impossible.

First the entire metal part is coated with a masking compound and allowed to dry. Using a sharp-bladed knife to cut through the cured mask, and a suitable template to guide the knife, the design is transferred to the part. The mask is then peeled from those areas to be chemically milled, and the part is dipped in or sprayed with a chemical solution to etch away the unmasked areas. Caustic soda is one of the major constituents in the etchant to mill aluminum. Magnesium, titanium and stainless steel are chemically milled in acid mixtures which typically are blends of sulfuric, nitric, hydrochloric and hydrofluoric acids.

Chemical milling has been applied successfully on a mass production basis to aluminum, magnesium, titanium, mag-thorium, Inconels, Monels, carbon steels and steel superalloys. It is used widely in the aircraft and missile fields where great weight savings can be achieved over machine milling. Both castings and forgings have been shaped by chemical means. Electronic circuits, steel shipping containers, pump impellers, radar aerials and decorative paneling are among the products outside the aviation field to which chemical milling has been applied.

Sodium Coolant from Reactors Studied for Use In Radiation Processing

The Atomic Energy Commission has contracted for a feasibility study on using the sodium reactor coolant at the Hallam Nuclear Power Facility as a high-level radiation source for industrial processing. The study will investigate the technical feasibility of using the radioactive sodium coolant for industrial radiation processing and of integrating such a radiation processing plant with the nuclear power facility being built at Hallam, Nebraska. Included will be a preliminary design study for the radiation processing plant.

Feb. ★ **U.S.I. CHEMICAL NEWS** ★ 1959

CONTINUED ***Sodium***

the U.S.I. laboratories have developed a new route to Grignard reagents as follows:

(a) $RCl + 2Na \longrightarrow RNa + NaCl$

(b) $RNa + MgCl_2 \longrightarrow RMgCl + NaCl$

Sodium is a less expensive starting material than magnesium, and less hazardous hydrocarbons can be substituted for ether as a solvent. In addition, higher yields are obtained with the sodium process.

Another halogen replacement reaction employs chlorobenzene in a sodium dispersion to yield phenylsodium, which can be reacted with toluene in a hydrogen substitution reaction to give benzylsodium. Phenylsodium, benzylsodium and many other organosodium compounds can be reacted with metallic halides such as $AlCl_3$, BCl_3, etc. to yield corresponding organometallic compounds.

Further details on the syntheses possible with organosodium compounds are given in U.S.I.'s free booklet "Sodium Dispersions".

Other Uses for Sodium Dispersions

A suspension of sodium hydride in mineral oil is easily produced by treating a sodium dispersion with hydrogen gas at 250-325°C and 200-500 psi hydrogen pressure.

Sodium dispersions are used to reduce nitriles to amines, ketones to alcohols, metal halides to finely-divided metals, esters to acyloins. They are employed to prepare sodamide and sodium acetylide. These reactions represent only a portion of the possible applications for sodium in finely-divided form.

Sodium Removes Impurities

Finely-divided forms of sodium are also being used to remove impurities from petroleum fractions and other hydrocarbons that do not possess conjugated double bonds. For example, coke oven producers of benzene, toluene and xylene are finding it difficult to compete with corresponding petroleum-based materials in so far as purity is concerned. Particularly, thiophene content is too high. However, by means of a novel U.S.I. process, coke oven aromatics can now be desulfurized with finely-divided sodium.

CONTINUED ***Zirconium***

using zirconium sponge from U.S.I.'s own pilot plant—forerunner of the present Mallory-Sharon installation.

In this instance, of course, initial zirconium cost was not a factor. However, the extremely long service life of the material, and the freedom from maintenance problems, bear out Mallory-Sharon's contention that zirconium is very economical over the long pull in applications where lower-priced metals just do not stand up.

In the recent past, zirconium has been a costly material and its availability for industrial applications has been limited. Now, with a million pounds per year of the metal available to industry from the Mallory-Sharon plant alone, costs are continually being reduced. It is possible to foresee fabrication of zirconium parts at costs only 3 to 5 times higher than for equivalent parts in stainless steel. In most cases, improved performance with zirconium will much more than offset the cost differential.

After 14 months in acid service, zirconium-stemmed control valve still operates at Mallory-Sharon zirconium plant, Ashtabula, Ohio.

TECHNICAL DEVELOPMENTS

Information about manufacturers of these items may be obtained by writing U.S.I.

New bottle carrier of heavy-wall polyethylene, designed for safe intra-plant transport of one-gallon bottles of corrosive chemicals and solvents, is now on market. Carrier said to prevent breakage, also to contain bottle contents. **No. 1440**

Eight longer-lived radioactive isotope standards, supplied until now by the National Bureau of Standards only, are available commercially. They are cesium-137, cobalt-60, iron-59, radium D+E, strontium-90, sulfur-35, tantalum-182 and thallium-204. **No. 1441**

New ultracentrifuge auxiliary permits separation, identification and characterization of materials up to 120° or down to 0°C. Broadens ultracentrifuge use in fields where solutes are not soluble enough at normal temperatures. **No. 1442**

Diphenyldidodecylsilane can now be obtained in limited commercial quantities as a new hydraulic fluid for systems subject to temperature and environmental extremes. Claimed to have good lubricating properties. **No. 1443**

Series of data sheets on tank truck shipment of liquid chemicals is now being sold. 35 sheets now available, each on a different chemical, give data on suggested equipment, loading, handling, safety, clean-up, etc. **No. 1444**

Over 200 organo-metallic compounds are cataloged in new brochure now available. Listed by main constituent such as boron, tin. Physical constants given for research chemicals, specs and uses given for commercial chemicals. **No. 1445**

170 Standards for fire safety are compiled in new, 6-volume, 1958 edition of National Fire Codes, now being sold. Includes 38 new or revised standards. Volumes on fluids, solids, buildings, extinguishers, electrical, transport. **No. 1446**

Non-flammable phosphoric acid type cleaner for most metals has been developed. Said to remove rust, metal oxides, oil and grease rapidly in one simple operation. Leaves light phosphate film on steel and zinc. Can be used hot or cold. **No. 1447**

New boron analyzer, designed to measure boron content of liquid process streams continuously to ±1% by volume, is now on market. Detects B^{10} isotope of boron, works on neutron absorption principle. **No. 1448**

Tracer applications for study of organic reactions are discussed in new book now being sold. Intended to stimulate use of isotopes among organic chemists. Appendices list texts on isotope use, organic reaction mechanisms. **No. 1449**

For more information, turn to Data Service card, circle No. 33

marginal notes

Uranium Ore Processing, J. W. Clegg and D. D. Foley, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts (1958), 436 pp.

Reviewed by Norman Levitz, Chemical Engineering Division, Argonne National Laboratory, Lemont, Illinois

This new volume is a welcome addition to the growing library of works in the nuclear energy field. The editors have assembled, via their cooperating authors, a well detailed insight into the many phases of the uranium ore refining industry. Each author is actively engaged in the phase of operations that he has described.

The introductory chapters deal with geology, ore mining and sampling and analytical methods. These indicate the wide scope of the development work which was required to make a science of uranium refining.

The major portion of the book develops logically from a general description of chemical processes for refining various types of ore concentrates to the detailed descriptions of specific processes currently in use at a number of production centers. Most of the material applies to the uranium industry in the United States. However, techniques and descriptions of development work carried out in other countries are also covered. Flowsheets and equipment descriptions are covered in good detail. Some cost data are included. The newest technology in practice, including solvent extraction and ion exchange techniques, are treated in detail. Each chapter has an extensive bibliography, especially of the more recent literature, which permits further research into specific problems. The inclusion of a chapter on Health and Safety is noteworthy. A glossary of terms, especially on geology, would have been a helpful addition for the chemical engineer.

Thorium Production Technology, F. L. Cuthbert, Addison-Wesley Publishing Co., Inc., Reading, Massachusetts (1958), 320 pp.

Reviewed by John Barghusen, Chemical Engineering Division, Argonne National Laboratory, Lemont, Illinois

This book, containing practically all the information currently available on thorium production technology, is one of a series of twelve volumes presented to the official delegates at Geneva in September, 1958, by the

continued on page 24

marginal notes

from page 22

United States. The purpose of this volume is to present for the first time a compilation of the work sponsored by the AEC on the development of processes for the production of thorium metal.

A considerable amount of information is condensed in this volume, representing the work of several research laboratories on various phases of thorium production processing over a period of some fourteen years. Some of the material is not very well organized, and in places is slightly confusing. However, the author is to be commended for reviewing the voluminous amount of material and presenting it in an interesting and readable fashion.

The first two chapters present a review of the properties and uses of thorium metal and compounds. The remainder of the book is primarily devoted to the description of the processing techniques from extraction of thorium from monazite sand to the fabrication of the purified metal. The book concludes with two chapters devoted to the health and safety aspects of thorium production, and analytical testing procedures related to thorium metal production.

Of direct interest to the chemical engineer are the chapters devoted to the extraction of thorium from ores, purification of thorium concentrates, and preparation of the metal by reduction. These processing steps are presented in considerable detail, even though some of the information is actually outdated. All pertinent information on separating and purifying thorium compounds from rare earths, uranium and associated elements is presented. Of specific interest is the first complete description of the solvent extraction technique for purifying thorium concentrates. The author devotes a considerable portion of the book to the description of this process. Among the points covered are: evaluation of the solvent, chemicals affecting the extraction of thorium and contaminants, scrubbing of impurities from the solvent, recycle of solvent, etc. This is one of the few detailed descriptions of the application of solvent extraction to the separation and purification of inorganic compounds available today.

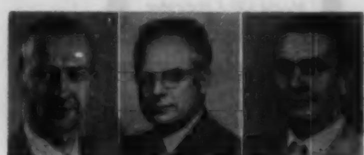
Although this book is not, by design, an exhaustive treatise on thorium, it will, however, find use as a source-book on all phases of thorium chemistry and metallurgy since the author cites over 450 references.

about our authors

R. E. Greenhalgh, who with **R. L. Johnson & H. D. Nott**, writes this month on *Mixing in Continuous Reactors*, says that this article attempts, perhaps for the first time, to "really define" the mixing model and its limitations. All three authors are with Dow Corning, Midland, Mich., Greenhalgh as supervisor, chemical engineering, Johnson as project engineer, and Nott as design engineer.

(l. to r.) Authors Greenhalgh, Johnson, Nott

Following an explosion in 1956 at Sun Oil's Marcus Hook air plant, **G. S. Cochrane** became intensely interested in air plant safety and "especially in infrared analyzers for continuously monitoring contaminants in liquid oxygen." One result of this dedication is the present article on *Continuous Monitoring of Hydrocarbon Contaminants in Low Temperature Air Separation Plants*. Cochrane has taken an active part in discussions of infrared analyzers at the Air Plant Safety Symposia at the recent A.I.Ch.E. National Meetings in Baltimore and Salt Lake City. His co-author is **E. J. Rosenbaum.**



(l. to r.) Authors Cochrane, Rosenbaum, Weedman

Hitherto unpublished details of the Phillips low-pressure polyethylene process are disclosed by **J. A. Weedman, O. W. Johnson & W. E. Payne** in *The Pressurized Centrifuge*. Weedman and Payne are with Phillips Petroleum, Johnson is with Dorr-Oliver.

Both **S. Lawroski** and **M. Levenson**, who report for CEP on significant aspects of last summer's Nuclear Conference in Geneva, were present there as members of the U.S. delegation. Both are now employed at Argonne National Laboratory, Lawroski as di-

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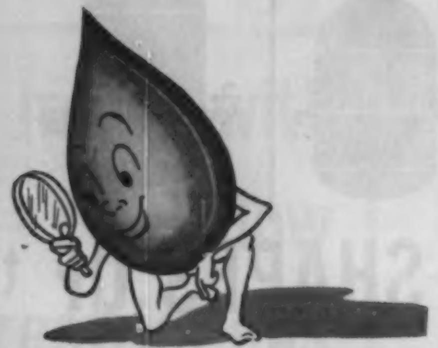
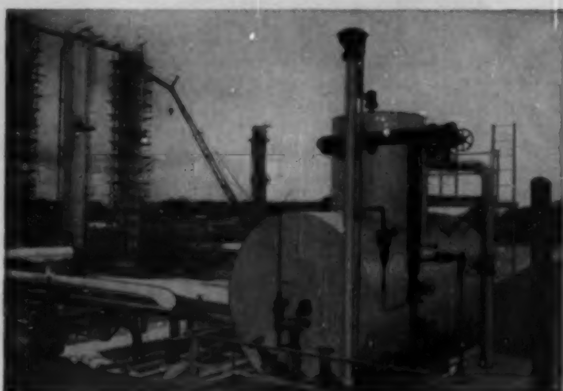
ALLIS-CHALMERS DEAERATORS

Pilot tray-type deaerator shown with continuous oxygen analyzer in test setup.



Looking for more effective deaeration?



Outdoor installation of Allis-Chalmers deaerator in southern chemical plant.

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This program includes the use of a specially built pilot deaerator with automatic oxygen analyzer and recorder. Operating factors and deaerating compartment design can be varied to study length of spilling edge of trays, heating area and method of flow. Results obtained with this setup are quickly translated into deaerators designed for optimum performance.

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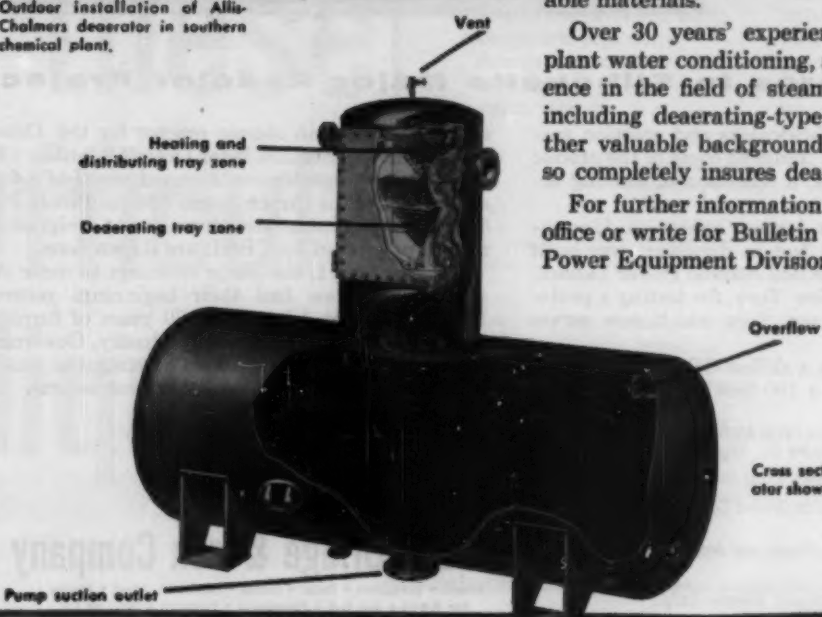

Cross section of tray-type deaerator shows water and steam flow.

ALLIS-CHALMERS

A-5674

For more information, turn to Data Service card, circle No. 10

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the meter with <u>NO</u> flow restrictions

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phosphate slurry
rayon viscose
magnesium carbonate slurry
phosphoric acid slurry
detergent concentrate
rosin size
starch solution
rubber copolymer
liquid latex
soda ash
sulphuric acid
70% sodium hydroxide
soap flow
styrol
magnesium hydrate

FOOD

beer
grape juice
apple juice
pineapple juice
tomato juice
milk
starch slurry
sugar syrup
coffee slurry
molasses

METALS AND MINING

pickling acid
sand slurry
ferrous chloride
limestone shale slurry
bauxite slurry
gilsonite slurry
aluminate liquor
uranium ore slurry
thickener mud
cement slurry
flue dust slurry
acid wastes

OIL INDUSTRIES

drilling mud
phosphoric acid
ethenol extract
scrubber recycle water
urea solution
nitrate solution
spent acid
sodium silicate & water
sodium chloride brine
tar-sand slurry

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all types of pulp stock
cooking liquors
spent liquors
bleaching chemicals
lime mud sluries
sizes
alum
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METER SIZES RANGE FROM 1/10 INCH TO OVER 6 FEET PIPE DIAMETER

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MAGNETIC FLOW METERS

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about our authors

from page 25

rector of the Chemical Engineering Division, Levenson as associate chemical engineer.

(l. to r.) Authors Rinehart, Watson, Schwennessen

"It is difficult to appraise statements of intent because currently everyone is for technology in the same way that everyone is against sin." This advice to engineers on selecting employers comes from **K. M. Watson,** who contributes to CEP this month the first part of his article on *Technologists in Top Management.* Watson is professor of chemical engineering at Illinois Institute of Technology.

J. S. Rinehart, author of *Fracturing Under Explosive Loading* has participated actively in the earth satellite tracking program and is the author of a book titled "New Weapons for Air Warfare." Currently, he is professor of mining engineering and director of the Mining Research Laboratory at the Colorado School of Mines.

W. K. Davis, who also reports from Geneva, is well known to readers of CEP. Former Director of Reactor Development for AEC, presently vice-president of Bechtel, Davis is eminently qualified to give an objective, penetrating analysis of the significance of the recent Geneva Conference, present and future.

W. A. Rodger *(The Chemical Engineer's Guide to Technology at Geneva)* is associate director of the Chemical Engineering Division at Argonne National Laboratory. He is vice-chairman of the Nuclear Engineering Division of A.I.Ch.E., and a member of its Pollution Control Committee.

J. L. Schwennesen, chief of the Chemical Processing Branch at AEC's Idaho Operations Office, contributes to CEP this month his insights on *Nuclear Fuel Processing—a Challenge for the Future.* In 1956, Schwennesen was awarded the Outstanding Service Medal and Award of the AEC.

FEBRUARY 1959

CEP trends

How Economic Changes in Europe Affect Us

The European Economic Community, or Common Market, is the more-or-less complete economic integration of six nations. The nations are France, West Germany, Italy, and Benelux. The ultimate goal, according to European observers, is to form one community, to a great extent politically as well as economically, with no trade barriers among them, free movement of labor, covertibility of currencies, and general economic unification. The ultimate result will be a free market of some 162 million consumers, and the first step toward a United Europe.

The European Free Trade Area is a more limited concept, advocated largely by Great Britain, which would contain the same six nations plus eleven others who, for one reason or another, do not wish to join the Common Market at this time. These latter nations are: Great Britain, Denmark, Switzerland, Austria, Norway, Sweden, Eire, Iceland, Portugal, Greece, and Turkey. Finland is a possible 18th member.

The Free Trade Area is, in essence, simply an attempt to have the same economic arrangements as the Common Market without the political unification involved. For American firms the result would probably be largely the same since both concepts include trade freedom inside the groups and trade barriers outside. The Free Trade Area would have some 285 million consumers.

Convertibility of currencies is part of both plans. Basically, economists explain, convertibility means that the currencies of different countries can be converted freely and without discount penalty into the currencies of other countries. In business terms this means that companies all over the world could do business anywhere without the artificial discriminations that have been the case in Europe for a long time. However, present convertibility is still only limited. In general, *external* convertibility has been restored, and any *nonresident* of most of the European countries can now convert currencies other than their own into U.S. dollars or any other currency. Restrictions are still on for residents. For example, a German can now sell in France, be paid in francs, and be able to freely convert the francs to dollars. A Frenchman still cannot convert francs to dollars in France. At the same time, much of the discrimination against "dollar-area" goods is still on.

What it means to U.S. firms

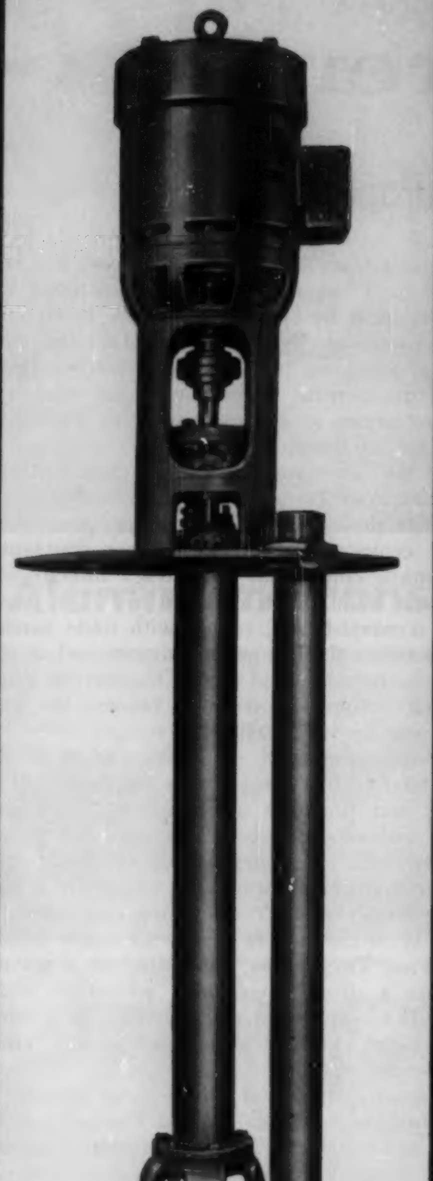
According to some experts, convertibility can mean more and simpler trading with Europe. Once currencies are freely convertible, discrimination against goods from dollar-areas will cease, and U.S. firms will have the assurance that a customer can pay in dollars if he has enough of the newly convertible currencies. Even the present limited convertibility, according to many businessmen, should result in an increase of both chemical sales and plant construction in Europe, providing trade barriers do not interfere.

One of the major results of the Common Market and/or the Free Trade Area will probably be an increased tendency for American firms, particularly chemical companies, synthetic rubber companies, petrochemical companies, etc., to go directly into Europe and build plants of their own. The reason for this, economists say, is that with trade barriers still up between the European countries and us, and with the barriers lessened among themselves, actual production within Europe may become the most feasible way for us to sell there competitively.

The engineering and equipment firms in this country tend to feel the problem for them will be different, and probably more serious. Until now, superior technology in certain areas, and greater familiarity with processes developed here, have given our engineering firms advantages which have weighed heavily in their competing successfully in Europe. With the advent of the Common Market and/or Free Trade Area, the European firms will move into a stronger economic advantage within Europe. The lowering of trade barriers, free movement of labor, etc., will offset much of our "know-how" advantage.

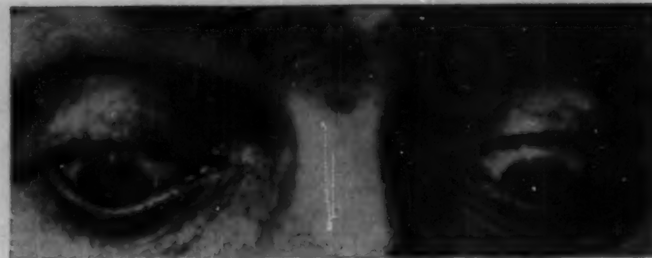
Undoubtedly, there will also be more competition from European countries *outside* Europe, possibly even in this country. With a more-or-less integrated economy inside Europe, and a common front outside Europe, the engineering and equipment firms of Europe are expected to have a powerful position from which to trade abroad. Firms that formerly competed because they came from different countries, are now expected to be working more closely together. Already at least one major engineering construction job has gone to a combined French-German bid which managed to be lower than that of an American company.

While it is far too early to assess the ultimate effects of either the Common Market, the Free Trade Area, or limited convertibility, these developments are certain to be far reaching, and are looked upon by many American firms as meaning stronger competition for themselves both in Europe and throughout the rest of the world.



GOULDS

PUMPS FOR INDUSTRY



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For more information, turn to Data Service card, circle No. 47

opinion and comment

As the editor sees it . . .

Conferring. Many chemical engineers attending the Cincinnati meeting must have noted the new feature that had been added! Located near the elevators on the registration floor was a "*CEP* editorial conference room." As it turned out, the conference operation was under way for several hours during each of four days. Both individuals and groups were interviewed.

Purpose of the conference room was, primarily, to obtain first-hand information from symposia chairmen and authors about their sessions and papers that would be of help and guidance in formulating plans and decisions relating to *CEP* and the other Institute publications.

Copious notes were taken which later proved highly valuable for a number of editorial purposes. It has now been decided to continue with a similar set-up at the forthcoming Atlantic City meeting.

All persons interested in discussing *CEP* publication matters are invited to "follow the signs," and if a conference is seen to be under way, set up an appointment with the secretary who will be there for that purpose.

Retrieval. A completely redesigned subject index made it first appearance in the December *CEP*, covering the 1958 volume. Several innovations were incorporated, which it is hoped will enhance the usefulness of the information contained in many of the articles published. Perhaps one of the most significant steps taken was to separately index such topics as "correlations" — 68 entries — and "coefficients"—18 entries. Such listings point up functions, relationships, etc. in addition to the normal listings by principal subjects.

Although *CEP* is not primarily intended as a repository for information-retrieval, it is believed important to make the information in the magazine's articles broadly identifiable.

Incidentally, thanks is due C. H. Mantell for his efforts in bringing these concepts to the attention of CEP's editorial staff, and advising as to their practical use.

Catching up. At a recent briefing of representatives of Non-Governmental Organizations at the United Nations (of which the A.I.Ch.E. is now one), Mr. Andrew Cordier, executive-assistant to the UN Secretary-General, spoke of the development of world organization as having taken place more rapidly than the development of a sense of world community. "We are one world in a technological sense," stated Mr. Cordier.

This concept can obviously be applied to other fields. Take, for example, the matter of unification of the engineering profession. Here, as elsewhere in the modern world, the machinery for group inter-action is probably better developed than the sense or spirit of cooperation, or group identification. Yet one cannot reasonably blame or reject the machinery for group inter-action. Instead, it would seem essential for each individual to seek and accept the areas upon which community spirit can be firmly built, whether for the UN or engineering unification. J.B.M.

"What's New?"

Recently, an International Conference on Scientific Information was held in Washington, D.C. This was under the auspices of the National Science Foundation, the National Academy of Sciences—National Research Council, and the American Documentation Institute. Among the problems discussed was how the scientist obtains information and how he learns of the work of others. A rather interesting group of facts was unearthed. Scientists in one study, on being asked how they learned of work crucial to their own, gave top priority to *casual conversation*, followed by *journal reading*. In another report, "three tools stood out—regular scanning of journals, attendance at meetings and lectures, and face-to-face contacts with colleagues."

Among "sources of ideas for current project" were listed, in order of importance, "own previous work, colleagues, and reading of literature." The order may vary: the percentage of those who list one means above another—above conversation—may be higher in one study than another, but essentially it seems that meeting colleagues and talking with them, reading current literature, and attending meetings are the prime sources of ideas.

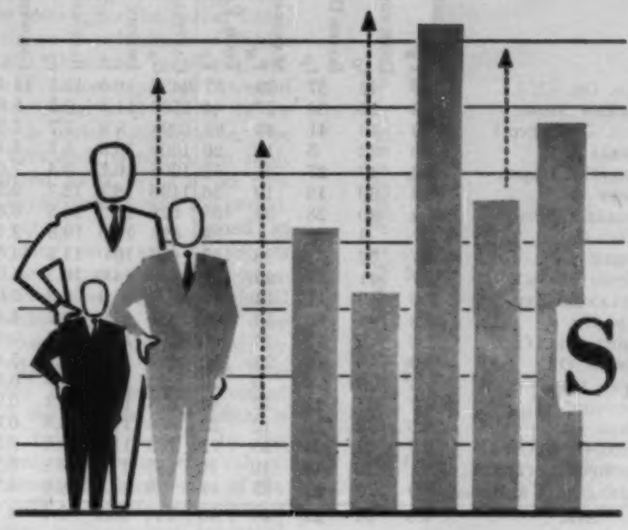
How better in our chemical civilization to tap all these sources than through A.I.Ch.E. activities? Aside from producing most of the chemical engineering literature, the Institute holds meetings that are famous for corridor conferences and "bull sessions." Regular attendance at meetings of his professional society profits the chemical engineer—and his organization. Possibly the temporary economy in not approving trips for the engineering staff appeals to comptrollers, but new ideas, and inspiration for new ideas, are the coin that pays off in the end.

This March A.I.Ch.E. meets in Atlatic City. This and the other meetings this year deserve the attention of every chemical engineer:

Kansas City	May
St. Louis	September
San Francisco	December

Here he will be caught up in the full flow of the new in chemical engineering and be carried along to ideas for better and more efficient operation. He may be surprised at where the casual greeting, "What's new?" takes him—and how far. F.J.V.A.

Technologists in Top Management: Part One



The Business SUCCESS Factor

Kenneth M. Watson
Illinois Institute of Technology, Chicago

An attempt to quantitatively relate the degree of management participation by the technologist to the financial performance of major companies. Part 2, to be published in the near future, will consider further interpretations of the factors developed.

Grateful acknowledgment is made of the assistance of Neal D. Smith who developed the computer program used in this study and of Catherine C. Watson, without whose research the project would not have been possible.

The free-enterprise system is fighting for its life in a world-wide competition which is basically technological in character. The strongest defense of free enterprise is its success. To maintain this margin of superiority will require continued increase in the quantity and particularly the quality of our technology and technologists. In this situation, study of the factors determining business success and the relationship of technology to it is of paramount importance.

It was with such concern in mind that a study was undertaken in the hope of developing information which will be helpful to business in improving its success and at the same time lead to greater participation of technologists in the responsibilities and benefits of business.

In the study reported herein, a *business success factor* was developed by evaluating and combining annual profit on invested capital with rates of income growth and capital expansion. A technology factor was then developed by combining level of research and development activity with percentage participation of technologists in management.

The business and technological performances during the ten years 1948-58 are compared for 20 large oil companies and 20 large chemical companies on the basis of readily available published data. Companies having higher technology factors are found to show significantly greater success indexes. No significant relationship is found between business success index and either research level, or technological participation in management, alone. There are indications, however, that a high level of research activity may be a liability unless combined with a technologically perceptive management.

Such results are believed to provide standards of comparison which will be generally useful to managements, technologists, and investors.

Determination of Business Success Factor

The companies for the study were chosen from the 1957 *Fortune Directory of the Largest Industrial Corporations (2)* in which companies are rated by dollar volume of sales. The oil companies selected (as listed in Tables 1 and 3) are the Directory's first twenty, excluding Sunray-Mid-continent which was formed by merger during the period understudy.

continued on next page

Success factor

continued

Selection of the chemical companies was more difficult and arbitrary. It was desired to establish a group of companies in the general chemical business which are competitive with each other in as many areas as possible. Excluded were companies whose principal business is outside the chemical field, those involved in major mergers, and those for which complete data for the period were not available. Also excluded were those primarily engaged in direct consumer marketing of such products such as paints, soaps, fibers, and food products. Decision as to the principal business of a corporation is made difficult because often data are not published on the distribution of business volume. With these exclusions the remaining first twenty companies on the Fortune list were selected. They are listed in Tables 2 and 3. There was no conscious selection on the basis of either business success or technological activity and no change was made in the lists after the analysis was started.

Table 1.
Oil Company Data

		Technological					Financial				
		Research T_R	Officers t_O	Board Directors t_D	Management T_M	Tech. Factor T_F	Capital C_a	Income I_a	Reinvestment c_a	Growth g_a	Success AOR_a
1	Std. Oil (N.J.)	3.6	42	37	39	57	3436	16.3	11.1	11.4	19.5
2	Socony Mobil	3.5	22	30	27	44	1507	11.6	9.2	8.6	10.1
3	Std. Oil (Ind.)	7.9	46	41	43	82	1398	9.9	7.7	2.5*	4.1
4	Texas Co.	3.0	22	5	11	26	1306	15.5	8.7	8.4	16.8
5	Std. Oil Calif.	4.4	40	27	31	53	1205	16.7	9.4	7.0	16.3
6	Gulf Oil	3.4	30	13	19	36	1196	15.1	12.7	9.3	13.2
7	Phillips Petr.	7.4	40	28	32	68	628	12.7	10.8	6.6	8.4
8	Sinclair	3.7	2	0	1	19	623	13.0	10.3	2.1*	4.8
9	Shell	13.7	52	31	38	105	617	19.0	11.2	4.5	14.4
10	Cities Service	1.7	41	23	29	37	429	14.0	10.3	-1.0*	2.6
11	Atlantic Ref.	7.0	19	11	14	48	379	10.9	6.6	2.0*	6.0
12	Sun Oil	5.3	49	50	50	76	351	12.9	10.2	4.4*	7.1
13	Tidewater Oil	2.6	46	17	27	40	299	12.4	8.4	0.9*	4.9
14	Union Oil	6.0	46	12	23	52	292	10.5	7.7	5.4*	7.2
15	Pure Oil	3.3	9	4	6	22	283	12.0	6.6	0.6*	6.0
16	Continental	4.7	22	23	23	46	278	16.4	7.2	0.9*	10.3
17	Ohio Oil	2.0	12	12	12	22	253	17.1	8.8	0.0	8.3
18	Std. Oil (Ohio)	9.7	27	24	25	72	199	11.1	6.4	2.2*	6.6
19	Richfield (Del.)	..	23	17	19	19	153	17.0	8.8	5.1	14.8
20	Ashland O & Ref.	5.9	20	12	15	44	78	14.5	16.6	4.7*	3.1
	Avg.	4.9	31	21	24	48	746	13.9	9.4	4.3	9.2

* *Growth rate not statistically significant*

Corporate size

Invested capital was selected as a basis of corporate size for this study because it is less dependent on success or on optional business policies. (See box on Invested Capital)

All financial data were taken from Moody's Industrials Manual *(5)*.

In Tables 1, 2, and 3, the companies are arranged in order of their *invested capital C* for the ten-year period 1948-59. The *average invested capital* C_a of each firm in millions of dollars is shown in columns 6 of Tables 1 and 2.

Net income rate

It was the viewpoint, during this study that the primary objective of business under the rules of the free-enterprise system is to generate maximum financial return on its invested capital.

Financial return is received by the owners or shareholders of a business in the form of dividends and also as *capital gains* resulting from increased value of their shares or equities. Dividends are paid out of net income, and *capital gains* represent the increased values of equities which result from increased earning power. Thus, both are related to *annual net income rate*. Dividends represent a distribution of current net income while capital gains are determined by the rates of increase of *net income rates*. Such increases may result either from increased efficiency of management or from expansion of invested capital by reinvestment of a part of the earnings or sale of new equities.

In Moody's, annual *net income to surplus I* appears in the income statement. *Percent annual net income rate i* (as related to invested capital) is determined by dividing annual net income by the average invested capital for the year. Such percentages over the ten-year period were averaged to obtain the average percentage income rate i_a, based on invested capital. Values of i_a are shown in columns 7 of Tables 1 and 2.

Frequently i or i_a are used as measures of business success. However, it is evident that consideration must also be given to reinvestment of earnings and to income growth rate in order to arrive at an accurate measure of overall return to the equity owners.

Business success factor *AOR*

The concept of *business success factor* is best introduced by a simple example. Consider a corporation which during a selected year has an average invested capital C of $100-million and during the year has a net income of $13-million corresponding to $i = 13\%$. It pays out 4 million dollars as dividends and reinvests 9 million dollars in the business. Thus, the invested capital increased from

Invested Capital and "Surplus"

Invested capital as used in this study is synonymous with the terms "net assets," "net worth," "book value," and "stockholders equity" as used in many annual reports and financial writings. It ordinarily differs little from "net tangible assets" which excludes intangible items such as good-will and patents.

In Moody's summaries, *invested capital C* is shown as of December 31, in the balance sheet. It is most easily derived from the statement of liabilities by adding together the values assigned to the capital stock, including preferred issues, plus the net surpluses. The average invested capital for a year is taken as the arithmetic average of that at the end of the year and that at the end of the preceding year.

The term *surplus* as used in Moody's is becoming unpopular and in many annual reports *capital surplus* is being replaced by statements such as *capital in excess of par value* and *earned surplus* by *earnings reinvested in the business.* The principal source of capital surpluses is the sale of new shares at greater than the par or nominal book value. Earned surpluses represent the accumulation of that portion of the *net income after taxes* or *net income to surplus* which is not paid out as dividends.

\$95.5 to 104.5-million during the year, corresponding to a capital expansion or *reinvestment rate* c of 9% per year based on *average invested capital* C.

Values of *average percentage reinvestment rates* c_a for the period 1948-58 are shown in columns 8 of Tables 1 and 2. Dividend payments, expressed as percentages of invested capital are equal to $(i - c)$ or 4% for the example under consideration. The average dividend payments are similarly derived as $(i_a - c_a)$ if no new equities were issued during the period.

New equities may be issued as stock dividends or by sale. The effects of such new equities are best visualized by considering the hypothetical but possible situation in which they are purchased on a pro rata basis by existing shareholders and the proceeds used to expand the invested capital of the business. The effect is to reduce net cash receipts by the shareholders, even to negative values, but to increase the book value of the equities held. Sale of new equities to outsiders is equivalent to initial pro rata sale to existing shareholders followed by resale. Thus $(i_a - c_a)$ represents the average annual percentage net cash receipts by the hypothetical constant owner group.

The actual values of corporate equities may differ widely from their book values, depending upon the earning power of the invested capital. In the example under consideration it may be assumed that the *net income rate*

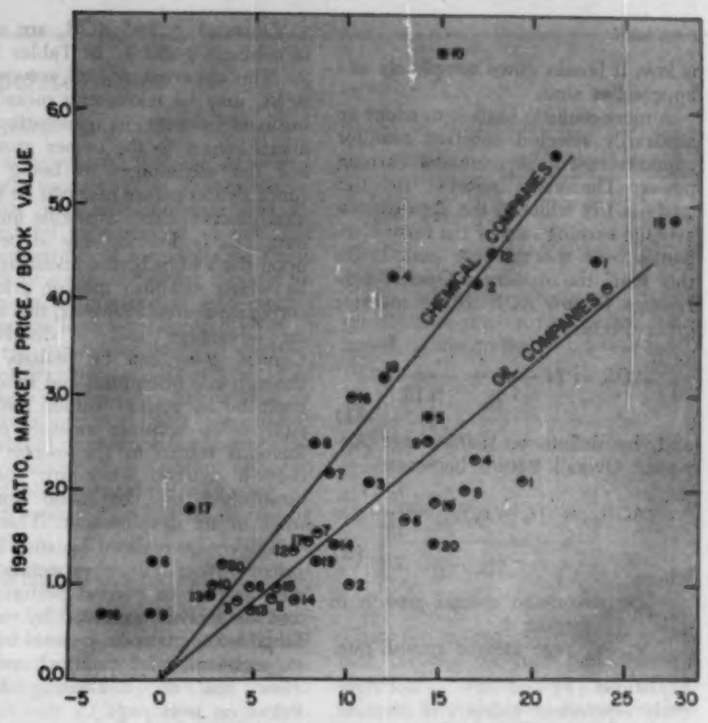


Figure 1. Relationship between current market price per book value ratio of common stocks and apparent over-all returns on invested capital from 1948 to 1958. (Numbers refer to Tables 1 and 2.)

is known to have been \$12.61-million per year at the beginning of the year and \$13.39-million at the end of the year, an annual increase in rate of \$0.78-million or a *percentage annual growth rate* g equal to 6% of the average income for the year. A realistic evaluation of the capital gain, is obtained by capitalizing this annual increment in earning power, ΔI = \$0.78-million, at an acceptable *percentage rate of return* i_c (or *rate of capitalization*).

Selection of a proper *rate of capitalization* i_c involves difficulties similar to those of the minimum acceptable return rate used by Happel *(3)* as a basis for the venture-worth method of project evaluation. The simplest procedure would be to capitalize the incremental earning power at the *current income rate* i. In the example this would lead to a capital gain of 0.78/0.13 = \$6.0-million or 6% of the average invested capital. The *total apparent return* to the owner group would then be the cash receipts, $i - c = 4\%$, plus the *capital gain* of 6% or a total of 10% based on the average invested capital. This is equivalent to reasoning that if the earning rate increases 6% the value of the equities should also increase 6%. The disadvantage of this simple method is that it assigns increased capital value to incremental earnings in situations where the *income rate* i

continued

Table 2. Chemical Company Data

		Technological					Financial				
		Research T_R	Officers t_O	Board Directors t_D	Management T_M	Tech. Factor T_F	Capital C_a	Income I_a	Reinvestment c_a	Growth g_a	Success AOR_a
1	Du Pont	14.1	50	47	48	63	1552	18.8	10.3	9.7	23.4
2.	Union Carbide	22.0	31	9	16	40	612	19.0	7.7	3.8*	16.8
3	Allied Chem.	..	5	8	7	7	317	13.9	7.5	4.4	11.1
4	Dow Chemical	25.6	62	52	55	82	274	14.0	11.2	8.9	12.4
5	Amer. Cyanamid	36.9	28	18	21	61	240	13.6	13.5	13.6	14.3
6	National Distl.	2.2	25	22	23	25	225	9.7	6.6	–4.8*	–0.5
7	Monsanto	31.3	32	36	35	68	218	13.5	14.5	9.6	9.0
8	Air Reduct.	6.5	29	23	25	32	190	11.0	9.6	8.0	8.2
9	Koppers	23.4	56	19	31	56	101	10.4	11.2	0.2*	–0.6
10	Merck	64.3	42	29	33	102	97	14.4	14.0	13.2	15.0
11	Gen. An. & Film	25.7	30	32	31	59	92	5.4	5.6	–4.5*	–2.1
12	Hercules Pwdr.	41.0	30	29	29	73	83	17.2	8.1	6.4	17.6
13	Int. Min. & Chem.	21.3	53	31	38	61	64	10.0	8.9	1.9*	2.6
14	Diamond Alkali	24.2	23	14	17	43	61	10.3	7.6	8.5*	9.4
15	Rohm & Haas	70.2	94	46	62	137	58	16.1	13.5	20.2	27.6
16	Va. Car. Chem.	22.5	57	10	26	50	42	8.9	5.2	–10.6	–3.6
17	Penn. Salt	21.8	0	10	7	30	42	8.2	7.9	1.9*	1.5
18	Hooker Chem.	15.2	47	32	37	53	39	13.5	15.8	13.8	12.0
19	Am. Agr. Chem.	12.8	0	0	0	14	35	12.1	4.7	1.0*	8.3
20	Atlas Powder	32.9	23	53	43	78	28	9.2	3.9	13.3	14.7
	Avg.	27.0	36	26	29	58	219	12.5	9.4	5.9	9.9

* *Growth rate not statistically significant*

continued

is low. It breaks down completely as i approaches zero.

A more realistic basis is to adopt an arbitrarily selected constant rate for *capitalization* i_c of increased earning power. The value selected for this study is 13% which is the approximate average earning rate of the forty companies over the ten-year period. On this basis the *Apparent Overall percentage Return AOR* to the investor group becomes:

$$AOR = (i - c) + \frac{i}{13} g \qquad (1)$$

and, by definition, the average Apparent Overall Return becomes:

$$AOR_a = (i_a - c_a) + \frac{i_a}{13} g_a \qquad (2)$$

where

g=percentage annual growth in income I.

g_a=average income growth rate.

Equations (1) and (2) are not rigorously equivalent unless i is constant. However, this a satisfactory approximation for most purposes.

Table 4. Analysis of Variance of AOR_a in Table 3

	Variation	Degrees Freedom	Variance σ^2	$\frac{\sigma}{\sigma^2_{ib}}$
Column means (T_F)	190.10	1	190.1	4.62
Row means (C_a)	81.23	1	81.23	1.97
Interaction	11.44	38	(ib) 41.13	
Within boxes	1551.53			
Total	1834.30	40		

Statistical F distribution (n_1=1; n_2=38)

Probability level	F
99%	7.35
95%	4.10
90%	2.85

Table 5. Classification by Management Technological Factor

		High T_M AOR_a	Low T_M AOR_a
Large companies	Oil	12.5	9.5
	Chem.	11.8	10.0
	Avg.	12.2	9.7
Small companies	Oil	7.2	7.6
	Chem.	11.0	6.6
	Avg.	9.1	7.1

Values of g_a and AOR_a are shown in columns 9 and 10 of Tables 1 and 2. The *apparent overall return rate* AOR_a may be taken as a measure of business success in generating financial return to the owner group. It has the advantages of being of a fundamental nature and can be evaluated precisely from available financial data. It is in no way dependent upon the whims of the investing public which establish market prices of corporate shares. However, this is both an advantage and a disadvange. *Capital gains* can be realized only through sale of equities and such sales must be at market value. Thus the *AOR* is an accurate measure of *real* financial return to the owner group only if market prices are correctly established by the same concepts used in its development. This ideal will never be realized because market prices reflect future expectations as well as past or current performances and are heavily weighted by such intangibles as glamour, general business expectations, and political outlooks. (See box on Evaluating Market Prices on next page.)

Role & Effect of Technologist

The National Research Council periodically conducts a survey which is published as the "Industrial Research Laboratories of the United States." The tenth edition *(6)* of this directory appears to present data of about 1954 which is not far from the middle of the period under study. Accordingly, the data from this volume are taken as average levels of research activity during the period.

Table 6. Classification by Research Level

		High T_R AOR_a	Low T_R AOR_a
Large companies	Oil	9.6	12.2
	Chem.	10.0	11.8
	Avg.	9.8	12.0
Small companies	Oil	6.0	8.8
	Chem.	13.4	4.2
	Avg.	9.7	6.5

In column 1 of Tables 1 and 2 are values of T_R the number of professional personnel, per ten million dollars of invested capital, listed as engaged in research and development *(6)*. Only technologists* definitely classified in the technological professions such as engineering, chemistry, physics, mathematics, geology, metallurgy, entomology, and the like are included in these figures. In all cases the research personnel of subsidiary companies (more than 50% owned) are included with those of the parent company.

It will be noted that capital invested in the chemical industry is protected by over five times the research activity existing in the petroleum industry. This difference is to be expected in comparing a completely creative industry with one which has a major portion of its capital invested in natural resources having long pro-

continued on page 42

Notation

AOR = apparent overall percentage return on invested capital during 1948-58

AOR_a = apparent overall return rate on invested capital during 1948-58

c = percentage annual rate of capital expansion

c_a = average rate of capital expansion 1948-58, percent per year

$C_0, C_1, C_2, C'_0, C'_1$ = constants in income-time polynomial equations

C = invested capital, dollars

C_a = average invested capital, 1948-58, $\$10^6$

g = income growth rate, percent, per year

g_a = average income growth rate, 1948-49

i = annual net income as percentage of invested capital = 100 I/C

i_a = average percentage income rate for 1948-58

i_c = percentage income rate used to capitalize income growth

I = annual income, dollars

I' = annual income, dollars, calculated from best least-squares equation

T_R = number of technologists in research and development per \$10-million of average invested capital (0.1 C_a)

t_D = percentage of listed directorates filled by technologists, 1948-58

t_O = percentage of listed officerships filled by technologists, 1948-58

T_M = management technological factor

T_F = average over-all technological factor

τ = time, years

Evaluating Market Price of Corporate Shares

It is not the object of this study to develop a method for evaluating market prices of corporate shares. However, it is evident that the methods used are applicable to this problem if they are directed toward the evaluation of trends with time of *i*, *c*, *g*, and *AOR* instead of average values over a ten-year period. A desirable modification in such studies is the introduction of a time lag of perhaps one year between the values of *c* and *g* used in evaluating *AOR*. This is to correspond to the inevitable delay between capital expansion and increased earnings.

Since greatest interest is in common stocks, a market-price-evaluation procedure must extend the *AOR* to current conditions on the basis of the latest information and then convert it to apparent dollar return by multiplying by the *current invested capital*. The *dollar apparent return* per share of common stock is then obtained by subtracting dividends payable to preferred stocks and dividing by the current number of common shares.

It is evident that any correlation between ten-year average *AOR* values and current market prices must be only approximate because of neglect of the foregoing factors. However, a rough correlation exists as shown in Figure 1, in which the approximate current ratio of price to book value per common share is plotted against the 1948-58 *AOR*. The idealized industry average lines on Figure 1 correspond to an average apparent overall return of roughly 4% on market price in the chemical industry and 6% in the oil industry, if the average performances of the past ten years are continued. The lower prices of oil stocks in comparison to past performance may be associated with the uncertainty of the Middle East situation or the ever-present threat of government regulation or increased taxation.

Deviation of an individual company from the industry average lines of Figure 1 may have any of a variety of significances. It may result from recent changes in prospects due to favorable or unfavorable current earnings. It may reflect public enthusiasm over a new product or project, or response to institutional advertising. On the other hand, it may merely indicate an abnormal ratio of preferred to common shares or the effects of changes in corporate financial structure through issuance or retirement of equities.

Long-term debt

It is recognized that the *AOR* as a *business success factor* ignores the instability and risk considerations indicated by factors such as the ratio of long-term debt to net assets. There has been a trend toward increase of this ratio by conversion of preferred stocks into long-term notes.

These considerations are omitted from this study on the theory that existing government regulations of corporate practices plus the limited availability of creditor funds make the accumulation of long-term debt an acceptable practice for extending invested capital and thereby increasing success.

Mathematical evaluation

For evaluation of the *business success factor* it is necessary to establish significant values of the *capital expansion rate c* and the *percentage income growth rate g*. The latter is particularly difficult to evaluate because of the considerable fluctuations of annual income which result from variations in business conditions, accounting practices and year-end adjustments. To serve as a basis for evaluating growth, *polynominal equations* were derived by the least-squares method to represent the *total income I* of each company as best average functions of time τ in years. The methods used are described in standard texts on statistical methods *(1)*. Both a linear and a quadratic equation were derived for each company. Thus,

$$I' = C_0 + C_1\tau + C_2\tau^2 \qquad (3)$$

or

$$I' = C'_0 + C'_1\tau \qquad (4)$$

where I' is the *calculated income* during the year τ.

Because of the considerable scatter in the data the residual unexplained variances of each correlation were calculated. The equations were tested for statistical significance by comparing their residual variances against each other and against the variance from a simple mean in the *F* test *(1)* at the 5% significance level.

These calculations were carried out on an electronic computer with a matrix program which evaluated the five equation constants and the three corresponding residual variations in a single operation.

With a significant correlation between income and time the *percentage growth rate* at any time is obtained by differentiation. Thus,

$$\frac{g}{100} = \frac{dI'}{I'd\tau} = \frac{C_1 + 2C_2\tau}{C_0 + C_1\tau + C_2\tau^2} \qquad (5)$$

where g = *percentage annual income growth.*

The *average percentage income growth* over the ten-year period is obtained by integration of Equation (5):

$$\frac{g_a}{100} = \int_{\tau_1}^{\tau_2} \frac{g\,d\tau}{100\,(\tau_2 - \tau_1)}$$

$$= \int_{I_{\tau_1}}^{I_{\tau_2}} \frac{dI'}{I'\,(\tau_2 - \tau_1)} = \frac{\ln I'\big|_{\tau_1}^{\tau_2}}{\tau_2 - \tau_1} \qquad (6)$$

Thus, the average percentage growth rate for the ten-year period is ten times the natural logarithm of the ratio of the calculated *annual income* at the end of 1957 to that at the beginning of 1948. As the income correlations were based on *annual average incomes* corresponding to the middle of the year, the integration of Equation (6) was carried out from $\tau = -0.5$ to $\tau = 9.5$ where $\tau = 0$ for the middle of 1948 and $\tau = 9$ for the middle of 1957.

The *average (calculated) growth rates* g_a, shown in column 9 of Tables 1 and 2, were calculated from Equation (3) where it was statistically significant; otherwise, Equation (4) was used. An asterisk in column 9 indicates a growth rate which is not statistically significant, as such, because of the irregularity or scatter of the income pattern.

Changes in invested capital are of a cumulative nature and ordinarily do not show the extreme fluctuations that characterize income rates. Accordingly, no equations were fitted to the invested capital data and the *average percentage annual expansion of capital* c_a was calculated by an expression analogous to Equation (6),

$$\frac{c_a}{100} = \left(\frac{dC}{Cd\tau}\right)_{avg.} = \frac{\ln C\big|_{\tau_1}^{\tau_2}}{\tau_2 - \tau_1} \qquad (7)$$

In column 8 of Tables 1 and 2 the values of c_a are based on *average invested capital* in the years 1957 and 1948. Thus, c_a is the natural logarithm of the ratio of these two capital values, divided by 0.09.

continued

ductive lives.

(See box below on Definition of Technologist)

Technologists in management

The names of administrative officers and directors *(5)* of each of the selected companies were tabulated for each year under consideration. The officer group was taken as comprising the chairman of the board, the president, and the vice presidents, excluding the secretary and treasurer as engaged in basically nontechnological activities.

A search was made for biographical data *(4)* on each of the management names, where possible in at least two volumes covering the individual's period of tenure. All management positions were thus classified as filled by a *technologist*, a *non-technical individual*, or by an *unlisted individual.* Of a total of 9003 management-position-years investigated 80% were found to be filled by listed individuals. The percentage listing of directors was better than that of officers (82% vs. 76%) probably because of their longer tenure. In only three companies were the percentages of listings found less than 70%. These were Tidewater Oil (59%), Virginia Carolina Chem. (60%), and Atlas (61%).

In the oil group the average company was directed by an average board of 13.0 comprising:

2.3 technologists
8.5 nontechnical
2.2 unlisted individuals.

Its officer group, as here defined, numbered 10.6, including:

2.6 technologists
5.6 nontechnical
2.4 unlisted individuals.

In the chemical group the average company had a board of 12.7 comprising:

2.9 technologists
7.5 non-technical
2.3 unlisted individuals.

Its officer group numbered 8.6, including:

2.6 technologists
3.8 non-technical
2.2 unlisted individuals.

In columns 2 and 3 of Tables 1 and 2 are the *percentages of technologists among listed officers* t_0 and directors t_D, respectively.

To obtain a single factor T_M for use as a measure of the *participation of technologists in management,* t_0 and t_D were combined, with t_D given twice the weighting of t_0. This arbitrary weighting is based on the fact that the board is the ultimate authority representing the stockholders and is responsible for appointing the officers and setting general policy. On the other hand, the officer group should be included since it is generally the source of much of the initiative. The board frequently functions largely by a veto power, which, however, is absolute. Thus,

$$T_M = (t_O + 2t_D)/3 \qquad (8)$$

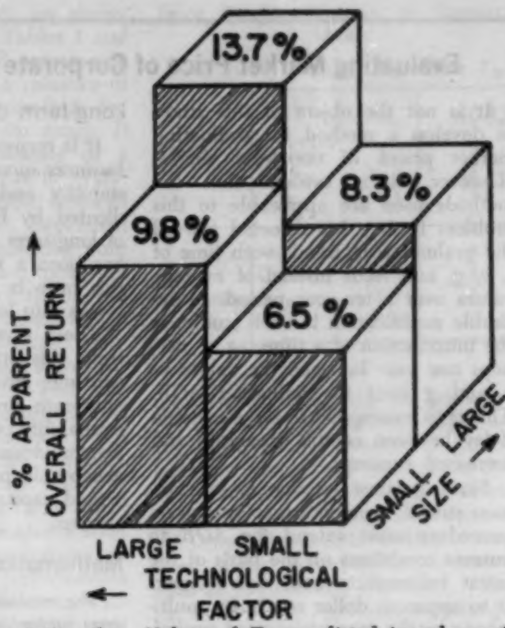


Figure 2. Average effects of corporate size and technological factor on business success factor AOR_g.

Values of T_M are listed in column 4 of Tables 1 and 2.

Technological factor

To obtain a single factor representing the level of technological activity in a company, the *management technological factor* T_M is combined with the *research factor* T_R. It is felt that these two factors should have approx-

Definition of technologist

To study the participation of technologists in management, it is necessary to define what is meant by a technologist. This requires arbitrary definitions to make effective use of the available biographical reference material. All biographical material used in this study was taken from "Who's Who in America" *(4).* This publication automatically solicits biographical data from the officers and directors of corporations of the size under study. Exclusion is therefore at the option of the individual.

For this study, a technologist in management is defined as one who meets any one of the following qualifications based on his published *(4)* biographical data:

1. At least ten years designated participation in technological work such as engineering, research, development, technical service, geological exploration, and the like.
2. A baccalaureate degree in engineering or a technological science plus at least four years designated participation in technological work.
3. A master's degree in engineering or a technological science plus at least three years of designated technological work.
4. An *earned,* not honorary, doctorate in engineering or a technological science.
5. Current active membership in the A.I.Ch.E. or another professional society in the technological field having comparable membership standards. The ACS was not recognized as qualifying in this category.

These definitions are designed to exclude individuals who graduated from a four-year college course in some area of technology and then immediately engaged in personnel supervision or sales work or transferred to a non-technological field such as law. Such individuals undoubtedly benefit from the smattering of technological information they acquire in an undergraduate course and some effectively extend their technological backgrounds. However, as a class it is believed that they should not be designated as technologists or considered as representative of the technological point of view.

	Success Factors — Small Technological Factors	Tf	AORa	Success Factors — Small Technological Factors	Tf	AORa
Large* Oil Companies	Std. Oil (N. J.)	57	10.5	Socony Mobil	44	10.1
	Std. Oil (Ind.)	82	4.1	Texas Co.	26	16.8
	Std. Oil of Cal.	53	16.3	Gulf Oil	32	13.2
	Phillips Petr.	68	8.4	Sinclair Oil	19	4.8
	Shell Oil	105	14 4	Cities Service	37	2 6
	Oil Co. Avg.	73	12.5		32	9.5
Large* Chemical Companies	Du Pont	63	23.4	Union Carbide	40	16.8
	Dow Chem.	82	12.4	Allied Chem.	7	11.1
	Am. Cyanamid	61	14.3	Natl. Distiller	25	-0.5
	Monsanto	68	9.0	Air Reduction	32	8.2
	Merck	102	15 0	Koppers	56	-.6
	Chem. Co Avg.	75	14.8		36	7.0
Large Company Average		74	13.7		36	8.3
Small* Oil Companies	Atlantic Rfg.	48	6.0	Tidewater	40	4.9
	Sun Oil	76	7 1	Pure Oil	22	6.0
	Union Oil	52	7.2	Ohio Oil	22	6.3
	Continental Oil	46	10.3	Richfield (Del.)	10	14.8
	Std. Oil of Ohio	72	6 6	Ashland Oil	44	3.1
	Oil Co. Avg.	59	7.4		30	7.4
Small* Chemical Companies	Gen. An. & Film	59	-2.1	Diamond Alkali	43	9.4
	Hercules Power	73	17.6	Va. Carolina Chem.	50	-3.6
	Int. Min. & Chem.	61	2 6	Penn Salt	30	1.5
	Rohm & Haas	137	27.6	Hooker Chem.	53	12.0
	Atlas Power	78	14 7	Am. Agr Chem.	14	8.3
	Chem.Co. Avg.	82	12.1		38	5.5
Small Company Average		70	9.8		34	6.5

* According to Invested Capital

Table 3. Success factor classification by Technological Factor and company size.

imately equal weight in a given competitive industry. Accordingly, the *overall technological factor* T_F is defined as follows:

$$T_F = T_M + T_R \frac{T_{Ma}}{T_{Ra}} \tag{9}$$

where T_{Ma} and T_{Ra} = *average management technological and research factors* for the industry group under consideration.

Thus, for the oil industry group

$$T_F = T_M + 4.9\ T_R \tag{10}$$

For the chemical companies

$$T_F = T_M + 1.07\ T_R \tag{11}$$

Values of T_F are shown in column 5 of Tables 1 and 2.

Correlation of business success with size, and use of technologists

In a comprehensive correlation of business success in a technological industry, the following factors are certain to be of importance in approximately the order of listing:

1. Individual ability and enthusiasm of personnel at all levels
2. Effectiveness of internal communications
3. Effectiveness of organizational patterns and procedures
4. Level of technological activity
5. Corporate size

Thus, of the minimum of five major independent variables, only two (Nos. 4 & 5) have been evaluated in this study. The others are unmeasured and uncontrolled and their magnitudes can be estimated only indirectly from the success achieved.

In such a situation the graphical and visual methods used in correlation of controlled engineering data are of no value because of the extensive scatter resulting from undetermined factors. However, this is a normal situation in the biological sciences, and in many business studies, and methods have been developed for arriving at valid conclusions by statistical analysis *(1)*.

Inspection of the corresponding values of T_F and AOR_a in Tables 1 and 2 confirms the expectation of a great deal of scatter. This is in part explainable by certain special situations. (See box below on Special Considerations)

It is evident from study of Tables 1 and 2 that companies which have high levels of technological activity show high success factors. On the other hand, a high level of technological activity in itself is no guarantee of success. Furthermore, excellent success factors may be achieved by a company with a low level of technological activity, presumably as a result of unusual strength in factors 1-3 of the foregoing list. In such a situation, the true role of technology is best evaluated by statistical study of averages.

In Table 3, the companies of each industry group are classified according to size and technological factor above and below the median of the industry group. It will be noted that for the individual industries and for the entire group, the average success factors of large companies and companies having high technological factors are higher. The averages of all companies are shown graphically in the three-dimensional diagram of Figure 2.

Although Figure 2 appears impressive in indicating definite trends of success with both technological factor and size, these cannot be accepted as valid conclusions without a statistical analysis of the data to make sure that the size of the sample (forty companies) is large enough in relation to the scatter of the data so that the

continued

Special Considerations in Some Companies

Du Pont has almost 50% of its invested capital represented by book value of the General Motors stock it owns. Thus, a more realistic value of T_R would be of the order of 28 with a correspondingly higher technological factor of 78.

General Aniline and Film has as its majority stockholder the Alien Property Custodian and is thus in effect owned and operated by the Department of Justice. Its success may be an indication of the efficiency of government ownership.

Since Allied Chemical and Richfield Oil did not report the numbers of their research personnel, it was necessary to assume zero and their technological factors are surely too low. In addition, Richfield is controlled and managed jointly by Sinclair and Cities Service. It probably has access to the technology of both parent companies.

Ashland Oil acquired two smaller oil companies during the period of study and probably was not fully reorganized as a result of this unusual expansion.

Success factor
continued

apparent correlation is unlikely to be the result of chance coincidence.

Results of such an analysis of variance *(1)* are shown in Table 4. This analysis indicates that there is over 95% probability that the conclusion is correct that companies with higher technological factors have greater success. However, there is less than 90% probability that the other conclusion indicated in Figure 2 is correct, namely that large companies are more successful than small ones.

In Tables 5 and 6 are classifications of success factor with size, *management technological factor* T_M, and *research level factor* T_R, respectively. No statistically significant trends were found, indicating that a combination of the two factors gives the best correlation with success.

It is interesting to note from Table 6 that in the oil industry as a whole, and in large companies as a group, the average success factor is higher for companies with low research levels. This might be interpreted as an indication that on the average research is a liability unless it is combined with a technologically perceptive management.

Interpretation

The results of this study indicate that technologists effectively contribute to success in business and participate in large numbers in the management of successful companies of the petroleum and chemical industries.

Although the supporting data show considerable scatter, it is concluded that for the average company it is good business to have a balanced management which includes technologists, and supports an adequate level of research. Technology appears to be of greater importance than size in assuring business success.

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To be presented at A.I.Ch.E. meeting, Atlantic City, N.J.

Mixing in Continuous Reactors

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The mixing of reactants and products in continuous reactors is usually too complex to describe by precise mathematics. Accordingly, continuous reactor design methods make use of simplified mixing models, which permit approximate solutions. Published mathematical treatments often use ambiguous terms to describe the model, and sometimes fail to define the limitations. A clearer understanding of the three basic mixing models and their limitations will aid the practicing engineer.

Model 1: Plug flow

The three basic mixing concepts can be defined by specifying the behavior of particles of feed. Plug Flow is defined:

Particles of feed leave the reactor in the same order in which they entered, and do not intermix or interact with each other.

This assumption is often the basis for tubular reactor calculations. Each particle of feed can be considered to be a small batch reactor. Since each particle is in the reactor for the same length of time (i.e., the nominal holding time, *V* cu. ft./*F* cu. ft./hr.), the conversion for any holding time can be estimated directly from batch data, provided other factors such as temperature changes and volume changes are known.

The curve of Figure 1 is a plot of instantaneous conversion, $1 - \frac{C_1}{C_0}$, vs. time held at reacting conditions for a *single* reaction (e.g., A → Products, A + B → Products, etc.) in a batch reactor. When the holding time V/F, equals 10 min. for a plug flow reactor, the conversion is 94%. Calculations based on plug flow will result in the maximum conversion for any given size of reactor.

Model 2: Complete mixing

The second major concept is Complete Mixing, which may be defined:

Particles of feed *intermix* with all other particles in the reactor immediately. Thus the particles lose their identity. The contents of the reactor are uniform and identical with those of the outgoing stream.

This assumption is frequently the basis for stirred tank reactor calculations. Since the contents of the reactor are, by definition, uniform, the reaction must proceed at only one rate: the rate corresponding to the concentration.

Figure 2 is a diagram showing a complete mixing reactor. The mathematical treatment is based on a steady-state-component balance:

$$F(C_{Ao} - C_{Af}) = \text{material converted per unit time} \quad (1)$$

For a single, first-order, homogeneous reaction, A → Products, the rate can be expressed:

$$\frac{-dC_A}{dt} = kC_A \quad (2)$$

Since concentration is uniform and

equal to the outflowing concentration, C_{Af}, the quantity of material converted per unit time is equal to the rate per unit volume multiplied by the volume, $kC_{Af}V$. When batch data of the type shown in Figure 1 are available, the rate $-dC_A/dt$ is taken at the concentration of interest. Therefore, the basic equation describing complete mixing is:

$$F(C_{A0}-C_{Af}) = V\ (\text{rate}) = -V\left(\frac{dC_A}{dt}\right)_{C_{Af}} \quad (3)$$

For a conversion of 77%, with the reaction whose rate is described by the curve of Figure 1, a holding time of V/F = 10 min. is required. The complete mixing model predicts the minimum conversion. Many articles have been published describing graphical and analytical methods of treating complete mixing. Eldridge and Piret (*1*) cover theoretical equations for many special cases in convenient table form. Bilous and Piret (*2*) describe a graphical method for treating complex reactions.

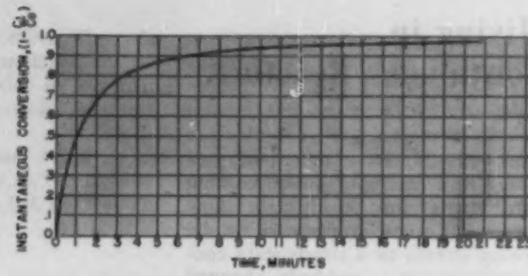

Figure 1. Batch reaction data.

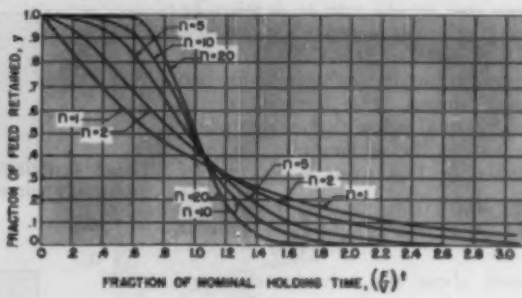

Figure 3. Holding-time curves.

Model 3: Zero intermixing

Zero intermixing represents a combination of plug flow and complete mixing:

Particles of feed are immediately and uniformly dispersed with existing particles in the reactor, *but the particles do not intermix* or interact with each other. Particles of feed leave the reactor randomly as a function of their statistical population.

Just as in plug flow, each particle acts like a small batch reactor. However, zero intermixing differs from plug flow in that each particle of feed is in the reactor a different length of time, and therefore each batch reaction proceeds to a different degree of completion.

If the particles in a reactor are uniformly dispersed, the relative probability that one particle will remain longer than another is a known mathematical function. MacMullin and Weber (3) developed the holding time curves of Figure 3. They defined a term, y, the fraction of a continuous feed held a time, t, or longer. The parameter, n, is the number of reactors in series. The relative probability, P, that a fraction of feed will be retained in the reactor at time t and leave before time $t + dt$ is the negative slope of the curves of Figure 3, $-dy/d[t(F/V)]$.

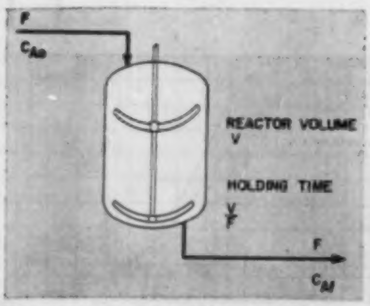

Figure 2. Complete mixing reactor.

A plot of P vs. t (F/V) for various numbers of reactors in series is shown in Figure 4.

The weight fraction, W, of material whose elements will have holding times between zero and infinity is

$$W = \frac{F}{V}\int_0^{\infty} P\,dt = 1.0$$

This equation can be used to predict the short circuiting in any fraction of material having any desired residence time in a continuous feed system in which the particles are uniformly dispersed. For example, given an F/V = 0.1, the fraction of material which has a residence time less than t_1 min. is

$$W_{t_1} = 0.1\int_0^{t_1} P\,dt$$

The remaining fraction, $1-W_{t_1}$, has a residence time greater than t_1 min. Residence time becomes important in the case of consecutive chemical reactions. This has been illustrated in an article by Sherwood (*4*) in which the yield of an unstable product is studied.

Since in the zero intermixing model each element acts as a separate batch reactor, the conversion in that element is dependent on how long it stays in the reactor. The average conversion of the outgoing stream was shown by Gilliland and Mason (5) to be the sum of the conversions obtained in each fraction of feed. The calculation may be performed by integrating the batch conversion data with the residence time data:

$$\left(1-\frac{C}{Co}\right)_{\text{avg.}} = \frac{F}{V}\int_0^{\infty} P\left(1-\frac{C_t}{Co}\right)dt$$

$1-\dfrac{C_t}{C_o}$ is the instantaneous conversion at residence time t of each element. The zero intermixing curve of Figure 5 was obtained by graphical integration using the batch data of Figure 1 and the probability function from Figure 4. The plug flow and complete mixing curves are included for comparison.

Residence-time-distribution studies

When material passing through a reactor fails to follow the probability relationship of Figure 4 because it is not uniformly dispersed, a study of residence-time distribution makes possible a more exact treatment. Gilliland, Mason, and Oliver (*6*) and

continued

Mixing in Continuous Reactors

continued

Dankwerts (7) have described procedures for studying residence-time distributions for steady-state flow systems. If some property of an inflowing stream to a steady-state continuous reactor is suddenly changed from one steady rate to another by injecting tracer material, for instance, it is possible to define the residence-time distribution by observing the outgoing stream. The fraction of the steady-state inflow of tracer which appears in the outflow at time t was termed by Dankwerts as $f(t)$. A plot of $f(t)$ vs. the group $t\left(\frac{F}{V}\right)$ reveals much about the behavior of liquid passing through the reactor. Figure 6 shows curves similar to those of Dankwerts for several representative time distributions encountered in continuous flow systems.

Perfect plug flow will, of course, never occur (Figure 6a). There will always be some departure because of longitudinal mixing as indicated in Figure 6b. Zero intermixing is indicated in Figure 6c. The equation for $f(t)$ can be shown $1-e^{-t(F/V)}$

The diagram of Figure 6d is representative of the case in which part of the fluid is trapped in stagnation or eddies while the rest flows through the reactor in restricted channels. The shape of the $f(t)$ diagram depends upon the relative times taken by various portions of the fluid to flow through the reactor. The slope of the $f(t)$ curve, $d[f(t)]/d[t(F/V)]$, equals specific relative probability, P', for a specific reactor and a specific flow rate. For departures from zero intermixing, Equation (6) becomes

$$\left(1-\frac{C}{C_o}\right)_{\text{avg.}} = \frac{F}{V}\int_0^\infty \left(1-\frac{C_1}{C_o}\right) P' \, dt$$

Equations (6) and (6a) are both based on no intermixing of particles. If intermixing does occur, correct values of C_i can be obtained from batch conversion data for only two cases: homogeneous zero- and first-order reactions. This is true because the intermixing of old and new particles and the resulting concentration gradients do not affect the over-all rate. For other than zero- or first-order the

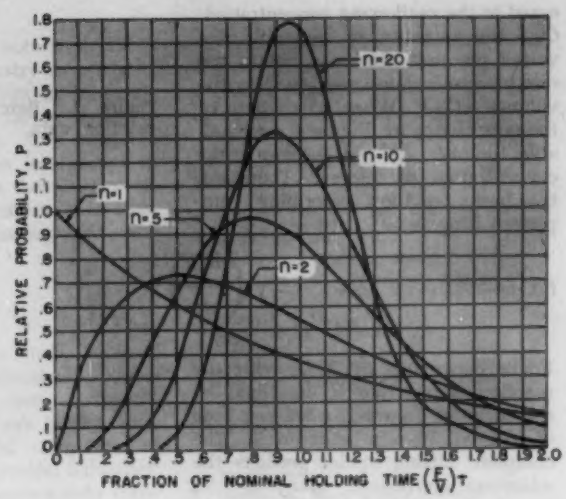

Figure 4. Relative probability curves.

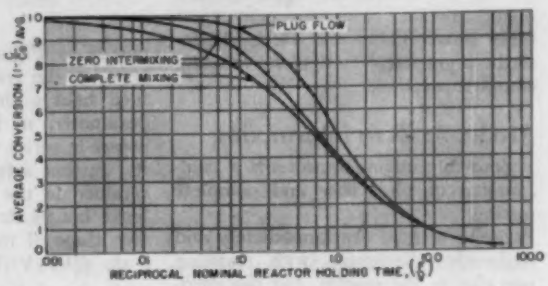

Figure 5. Theoretical limits of conversion for a continuous reactor for the reaction represented by Figure 1.

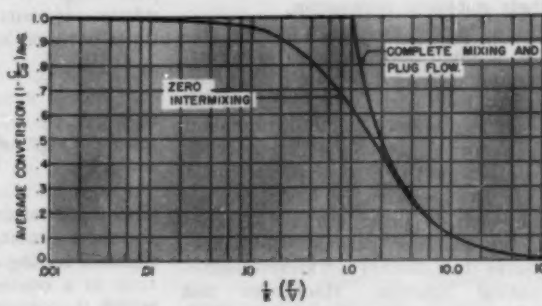

Figure 7. Conversion for zero-order reactions.

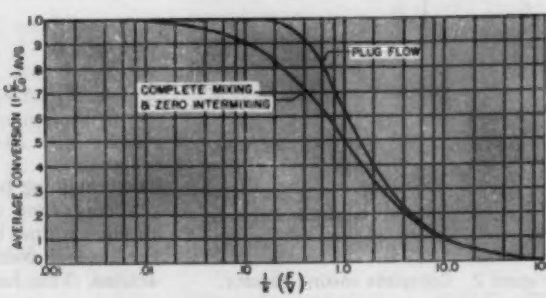

Figure 8. Conversion for first-order reactions.

chance of a molecule reacting depends on the other molecules it encounters. The nature of the encounters is not disclosed by a residence time study. A second-order reaction which correlates as a pseudo first-order cannot be treated rigorously for the above reasons.

Reactions of known order

Once the practicing designer has mastered each of these concepts, what can he do with them? How are they related? These questions can best be answered by looking at reactions of known order.

It is convenient to compare the three theoretical mixing models for the case of a single, homogeneous, uncatalyzed reaction which occurs without change in volume and for which the initial concentration of reactants is 1.0. The reaction may be written $aA \rightarrow$ Products, and the kinetic rate equation may be written

$$\frac{-dC_A}{dt} = k(C_A)^b \qquad (7)$$

Laboratory batch reaction data are often correlated in the form of Equation (7), where b, the apparent reaction order, may have any value, but is usually in the range between 0.0 and 3.0 and frequently has a value close to 1.0.

Zero-order reactions. The case $b = 0$, known as a zero-order reaction, will be examined first. A zero-order reaction, strictly speaking, is purely a theoretical concept; however, it is approached in such reactions as the cracking of petroleum and the copolymerization of butadiene and styrene. Since the reaction rate is constant, independent of concentration and time, the average conversion in a given size reactor will be the same when calculated by assuming either the plug flow model or the complete mixing model. This is shown in Figure 7, in which is plotted the average conversion, $1 - \frac{C}{C_0}$, as a function of $\frac{1}{k}\left(\frac{F}{V}\right)$ Neither the plug flow nor the complete mixing model accounts for the variable residence time of individual particles of feed. The zero intermixing model, however, accounts for those particles which have been in the reactor a period longer than the time required for complete reaction ($C_A = 0$ when $\frac{1}{k}\left(\frac{F}{V}\right) \leq 1.0$) and hence are occupying reactor space without contributing anything further to the over-all conversion. Thus the average conversion predicted by the zero intermixing model is less than that for the other models, as shown in Figure 7.

First-order reactions. When b in Equation (7), and a in the reaction equation are equal to 1.0, the reaction is first-order. For this case only, calculations based on zero intermixing will give the same result as those based on complete mixing. An example of a true first-order reaction is the decomposition of nitrogen pentoxide. The models of complete mix-

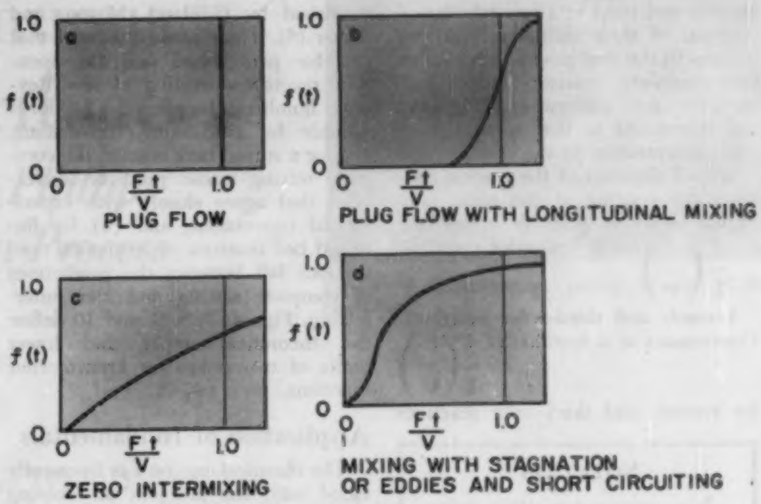

Figure 6. Residence-time-distribution curves.

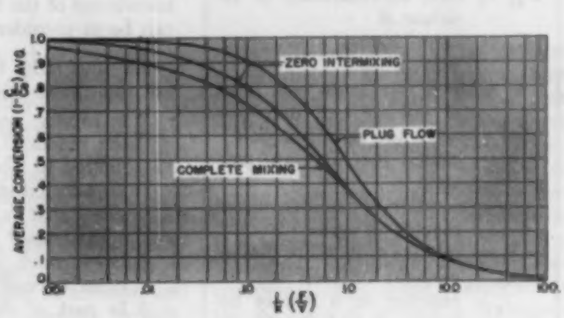

Figure 9. Conversion for second-order reactions.

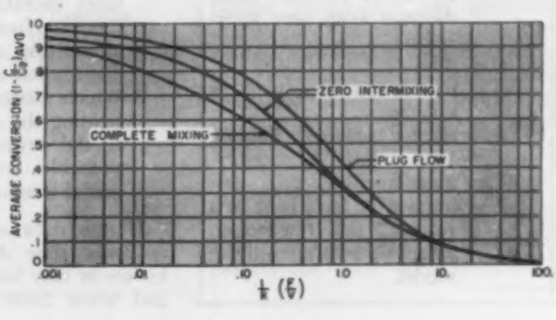

Figure 10. Conversion for third-order reactions.

. . . problem of finding a design for carrying out a reaction continuously.

continued from page 47

ing and zero intermixing both make the assumption that the feed is instantaneously and uniformly distributed throughout the volume of the reactor. The difference between the models is that in the zero intermixing model, individual particles retain their identity and react at a rate which is a function of their individual concentrations to the first power, whereas in the complete mixing model, all particles are uniformly distributed and intermixed so that there is only one concentration in the reactor, and hence all elements of the reactor contents are reacting at the same rate. Figure 8 shows plots of conversion vs. $\frac{1}{k}\left(\frac{F}{V}\right)$ for a first-order reaction.

Second- and third-order reactions. Conversions as a function of $\frac{1}{k}\left(\frac{F}{V}\right)$ for second- and third-order reactions in continuous-flow reactors are plotted in Figures 9 and 10. The curves may be taken as typical for reactions which have an order higher than 1.0. Experimental results for homogeneous second- and third-order reactions for various types of reactors have been published by Gilliland, Mason, and Oliver *(6)*. Their results showed that (a) for packed-bed and for open-tube reactors operating at low Reynolds numbers, the plug flow model is suitable for calculating conversions; (b) for a stirred tank reactor, the complete mixing model predicts conversions that agree closely with experimental conversions, and (c) for fluidized bed reactors, experimental conversions fall between the predictions of complete mixing and zero intermixing. Figures 7, 8, 9, and 10 define the theoretical upper and lower limits of conversion for known-order reactions.

NOTATION

b =	apparent reaction order
C_A =	concentration of reactant A
C_{A_0} =	initial concentration of reactant A
C_{Af} =	final concentration of reactant A
C_i =	instantaneous concentration
F =	feed rate, mass/unit time, or volume/unit time
$f(t)$ =	residence time function
k =	kinetic reaction rate constant
n =	number of perfectly mixed reactor in series
P =	relative probability that an element of feed will be retained in a reactor between (t) and $(t+dt)$, assuming zero intermixing model
P' =	specific relative probability for a reactor which deviates from zero intermixing
t =	time
V =	reactor capacity, mass or volume
(V/F) =	reactor nominal holding time
W =	mass fraction
y =	fraction of feed held in a reactor a time t or longer, assuming zero intermixing model.

Application of fundamentals

The chemical engineer is frequently faced with the problem of "coming up" with a design for carrying out a chemical reaction continuously. Often the application does not fall into one of the simple classifications thus far discussed. Nevertheless, a knowledge of the foregoing discussion can be of considerable aid.

To illustrate, the designer might ask such basic questions as:

1. Is mixing necessary to promote the reaction? If it is, can it be limited to lateral mixing, with as little longitudinal mixing as possible, that is, can plug flow be approached?
2. How much intermixing of particles occurs?
3. Is part of the fluid trapped in stagnation or in eddies, and, if so, what effect will this have on the conversion?
4. Is a narrow range of residence times necessary to make the desired product? What effect does intermixing of particles have on distribution of products?
5. Which mixing model is best for treating the case at hand? What is the order of magnitude of probable error if a particular model is assumed.

If rate data are available and if residence time distribution is either known or may be assumed, the upper and lower limits of conversion can be predicted. If the reaction is simple and homogeneous, a single well-stirred reaction vessel will give conversions close to those predicted by the complete mixing model.

If the reaction vessel is a long tubular type, or if it has several stages, the conversion obtained will be higher than that predicted by the complete mixing model, and will approach that predicted by the plug flow concept as an upper limit.

As pointed out earlier, the zero intermixing concept can, strictly speaking, be applied only to first-order, single, homogeneous reactions and to zero-order reactions. However, even with these severe limitations, the practicing designer may find it useful. Distribution of products for consecutive reactions occurring in continuous reactors may be estimated by integrating the batch-distribution data with the residence-time data. A heterogeneous reaction of two liquid phases in which the continuous phase is essentially a catalyst, and in which the discontinuous phase consists of particles of feed which are undergoing reaction, can be approximated by the zero intermixing concept for the case of a well-stirred reactor. The value of the approximation will depend upon the amount of coalescing of particles that occurs; if little coalescing occurs, then the approximation should be close. Similarly, a heterogeneous reaction of a finely divided solid in a liquid can be treated. Analytical solutions (and experimental verification) for the dissolution of a solid in a liquid under a variety of conditions were recently made available in a paper by Mattern, Bilous, and Piret *(8)*. The theoretical development was based on the zero intermixing model. Extension of the equations to describe heterogeneous catalytic reactions, ion exchange, leaching, polymerization, and crystallization was suggested.

In each of these and in similar instances the design engineer must decide how good the mathematical model is for his particular application.

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Development of
Pressurized Continuous Centrifuge
for Phillips' Polyolefin Process

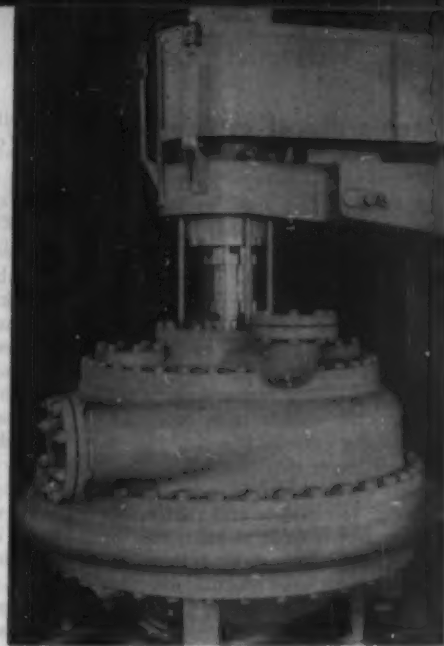

Figure 8. Commercial model Merco PC-30 centrifuge.

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A GENERAL review of the development of the Phillips low-pressure Marlex* polyolefin process has been given *(1)*. Successful commercialization of this revolutionary new process required the development of several types of process equipment. A need had existed for much of this equipment in other process applications, but only a program as extensive in scope as Marlex polyolefins could withstand the development expense. Now commercially available for the first time this equipment will find many applications in other fields. This paper describes a new process engineering tool, a pressurized disk-type nozzle-bowl centrifuge, jointly developed by Phillips Petroleum Company and Dorr-Oliver Inc. for the Marlex polyolefin process.

Review of problem

One important problem encountered in the development of a commercial process for manufacturing Marlex polyethylene, was the removal of spent, solid catalyst particles from the polymer solution discharged by the reactor. An analysis of the problem, followed by a survey of the many solids-liquid separation methods, suggested a disk-type centrifuge. Process conditions, however, imposed new requirements for commercially available centrifuges. In order to maintain the polymer in solution and to reduce solution viscosities to satisfactory levels, it was necessary to effect catalyst removal at elevated temperatures. At these temperatures the polymer solution had a vapor pressure of several atm., and it was necessary to use a pressurized centrifuge.

Discussions with manufacturers revealed that pressurized disk-type centrifuges were not only nonexistent but that no manufacturer was willing to undertake the development of such equipment. The major deterrent was the problem of sealing a high-speed shaft with both radial and axial movements against several atmospheres pressure. Phillips' engineers were confident this problem could be solved. Before undertaking the mechanical development of the pressurized centrifuge, however, it was deemed desirable to confirm by demonstration tests that centrifuging would satisfactorily remove the catalyst particles as predicted by theory.

Theoretical

A sedimentation analysis of the spent catalyst particles revealed the particle-size data shown in Table A.

continued

Table A.

Wt. % Catalyst finer than size	Particle size as Stokes equivalent diameter, μ
5	1.0
10	1.5
20	2.5
40	5
60	8
80	11
90	16
98	25
100	40

* *A trademark for Phillips' family of olefin polymers.*

Pressurized centrifuge

continued

Specifications for the finished Marlex polyethylene required the removal of about 99% of the spent catalyst particles in order that no more than eight parts of catalyst be left in one million parts of polymer solution. Since a centrifuge will preferentially remove the largest particles, this requirement meant that a large portion of particles smaller than one micron in diameter must be removed together with all larger particles.

Less theoretical treatment has been given to the design and performance of centrifuges than to any other unit operation according to Maloney *(2)*. A few papers have recently attempted to fill this void. Smith *(3)* and Ambler *(4)* have discussed several semiempirical methods employed by centrifuge manufacturers for estimating machine performance. Jury and Locke *(5)* have recently (since the time of this development) presented methods for predicting the performance of disk-

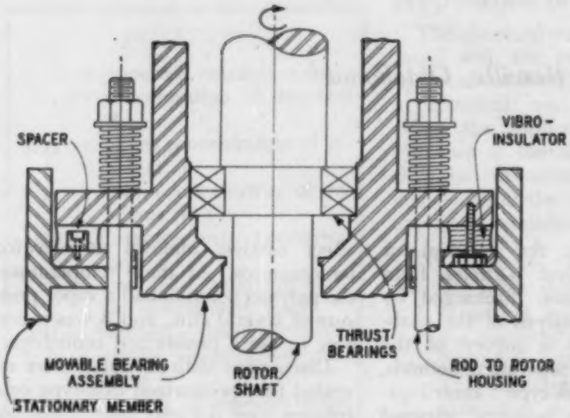

Figure 1. Details of rotor shaft suspension for Merco centrifuge.

type centrifuges: theoretical equations were developed and the results found to agree well with actual tests of a Merco disk-type centrifuge.

Application of the best available methods in Chemical Engineers' Handbook *(6)* and elsewhere indicated that a disk-type centrifuge probably had sufficient separation efficiency to meet the catalyst-removal requirements of the Marlex polyethylene process. Because of the unknown accuracy of the theoretical methods for a polymer solution with nonideal properties under never-before-tested pressure conditions, it was considered necessary to improvise a small disk-type centrifuge for demonstration tests before proceeding with the rather expensive development of commercial machines.

Test of improvised disk-type centrifuge

The only disk-type centrifuge found available with a case capable of withstanding several atmospheres pressure was an obsolete model milk clarifier. It was necessary only to install mechanical seals on the shafts of this machine to adapt it to operation at elevated pressures and temperatures. The disk bowl contained a stack of eighty disks with 1/16-in. disk spacing. Bowl speed was 7000 rev. per min. which developed a separating force of 6000 G's. Feed entered the machine at the bottom of the disk stack, passed upward through the narrow passageways beween the disks, and issued from the top as the clarified product. Solids, separated from liquid by the clarifying action of the disks, were thrown against the bowl wall and allowed to accumulate there. It was thus necessary to stop the machine for cleaning when the bowl filled with solids. While the test centrifuge was not truly a continuous one as desired for commercial Marlex plants, it did (1) provide a true test of the disk-bowl efficiency for catalyst removal, and (2) permit easy conversion to pressure operation for the preliminary tests.

Some difficulty was experienced with the improvised installation of the mechanical seals which, however, paid dividends later in the design of seals for the commercial-size centrifuges. Between seal failures, however, sufficient tests were completed to prove that a disk-bowl centrifuge of proper design would satisfactorily meet the catalyst-removal requirements of the Marlex polyethylene process. The next step was the development of a

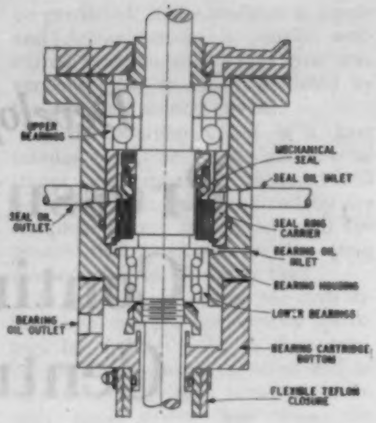

Figure 2. Mounting first seal-PC9 centrifuge.

pressurized disk-type centrifuge with provision for continuous solids removal.

Construction of pilot-model

Based on the successful demonstration tests with the pressurized milk clarifier and the fact that a substantial number of large machines would be required for commercial Marlex plants, the Merco Centrifugal Company (now a part of Dorr-Oliver Inc.) and Phillips Petroleum Company undertook the joint development of a pressurized, continuous centrifuge. The Merco Centrifugal Company had for several years built a disk-type, nozzle-bowl centrifuge with internal recycle which appeared to be adaptable to pressurization. An internal recycle of the nozzle-discharged solids stream to the bottom of the rotor permitted the solids to be concentrated and continuously withdrawn in a minimum of liquid through an external valve. Before building a commercial machine, however, it was deemed desirable to build a pilot model for test purposes. While the milk clarifier had demonstrated that the catalyst particles could

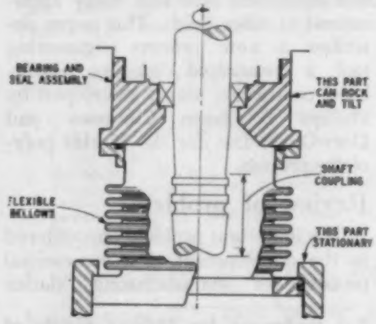

Figure 3. Original bellows closure.

be separated satisfactorily from polymer solution with a disk bowl, an equally important requirement—continuous removal of the solid particles from the machine under pressure conditions—had not been demonstrated.

The decision was made to modify a standard Merco pilot-model C-9 centrifuge to fit the required process conditions. Speed of delivery dictated a "canned" unit of the standard machine.

Four principal problems were encountered in modifying the C-9 centrifuge for pressure operation:

1. **Sealing a High-Speed Rotating Shaft Having Both Radial and Axial Movements.** Shaft-sealing problems were considerable since the basic method of rotor suspension used in the Merco centrifuge allows a free-floating shaft. By this method (Figure 1) the rotor is allowed to find its own center of gravity in moments of unbalance, thereby gyrating instead of vibrating. The then-present art of shaft sealing would not allow the general shaft radial movement inherent in the Merco design. This problem was resolved into two separate phases:

a. To seal the shaft at the required speeds

b. To take up the shaft radial displacement in a flexible connection

The seal was mounted as shown in Figure 2. It was a balanced-type mechanical face seal using a stellite running face and a carbon stationary face. Minimum radial displacement of the shaft at the sealing point was obtained by affixing the seal to the movable bearing assembly. Fortunately, the design of the basic Merco centrifuge isolates the bearings from the liquid being processed. In the pressure unit this allowed the running of the lower bearing in the polymer solution atmosphere. Lubrication supplied to this bearing became diluted but still sufficed.

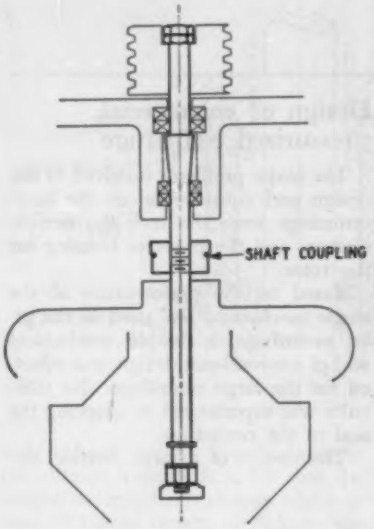

Figure 4. Model 9 with coupled shaft.

Shaft-and-bearing-assembly movement with regard to the stationary-housing components of the machine was accommodated by a flexible connection between the stationary centrifuge pressure shell and the movable bearing-seal assembly, neither of which was a rotating mechanism. The original design incorporated use of a metallic bellows-type flexible hose within which the shaft turned (see Figure 3.)

2. **Compensation for Rotor Stability Due to Thrust on a Single Protrusion Shaft.** No degree of reduced rotor stability could be predicted. However, to reduce the required flexible closure diameter, the cross-sectional area of which directly affected the pressure thrust on the bearing assembly, the normal shaft coupling (Figure 4) was discarded and a solid, nonjointed shaft was incorporated as shown in Figure 5. The standard Merco resilient mounting was then considered capable of coping with the conditions.

3. **Power Requirements Due to Seal Friction and to the Rotation of a Rotor in a Dense Atmosphere.** Additional power requirements stemming from the seal friction but primarily from the dense, polymer-solution atmosphere were affected by so many variables that accurate predictions were impossible. It was decided to test the pilot model at lower than the usual speeds until accurate data could be gathered. Extrapolation of results to larger equipment from several lower speeds would be just as accurate as those obtained at one high speed. Since the Merco uses a V-belt drive, speed changes could be made at test location with simple sheave changes.

4. **Pressure Shell.** The pressure shell presented no great problem, the shell and flanges being made of standard shapes. Adjustable height mountings were provided for the centrifuge housing, and required entrances for piping and adjustment rods were provided by packing gland arrangements.

The unit was completed, pressure tested, and delivered in six months. Factory testing was not justified because process conditions could not be simulated. Pilot testing, therefore, involved both mechanical and process problems.

Mechanical Performance. The pressurized Merco pilot centrifuge was installed in the polyethylene pilot plant for testing. Initial tests were made with solvent containing no polymer at process temperature and pressure conditions. Failure of the bellows-type flexible closure was at once experienced. Several replacements proved this type of closure to be unsatisfactory. The number of flexings developed by high speeds used up the normal life of such a device in a relatively short time. A solution was finally reached through the mutual efforts of Phillips and Dorr-Oliver engineers by using a reinforced Teflon sleeve operating at each end on a Teflon O-ring. This type of closure proved entirely satisfactory and a failure of such a closure has never been experienced, Figure 6.

Seal failure was a problem in early operation, but always occurred as a result of the breakdown of the external

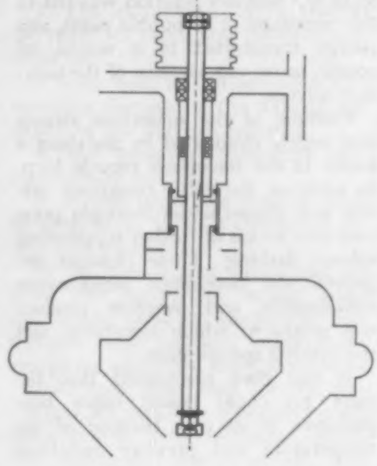

Figure 5. PC9 with continuous shaft.

lubricating-cooling system. A simple redesign of this system solved the problem of seal failure. However, the importance of this problem was recognized and taken into account when designing the commercial unit.

Process Performance. After the rather minor mechanical imperfections of the pilot centrifuge were corrected, attention was directed to its process performance. It was gratifying that no difficulty was ever encountered in removing solids from the nozzle-type bowl. No appreciable buildup of solids was encountered within the bowl and only infrequently did one or more of the nozzles plug, generally the result of upset operations.

As originally placed in operation,

continued

. . . major problems involved in the design and construction of the large centrifuge—seal, flexible closure, pressure housing for rotor.

continued

the pilot centrifuge did not produce an overflow polymer-solution product meeting the catalyst specification. The observation that the percentage of catalyst particles in the overflow product tended to decrease as the feed rate was increased, coupled with the fact that analyses of the overflow particles showed the same size distribution as particles in the feed, led to the correct conclusion that the overflow was receiving a constant source of contamination at some point external to the disk bowl. Temperature measurements and other observations indicated that part of the underflow stream was flashing as it discharged from the bowl nozzles. This flashing apparently caused some of the liquid underflow to be entrained into the overflow volute. Since the polymer solution was fed to the centrifuge at its bubble point, any energy transmitted to it would, of course, cause vaporization of the polymer solvent.

Flashing of the underflow stream was largely eliminated by installing a cooler in the underflow recycle loop. In addition, the entire centrifuge system was placed under inert-gas pressure as a means of further suppressing solvent flashing. These changes improved the centrifuge performance considerably and overflow product was produced which sometimes met the catalyst specification.

It was then recognized that the inert gas could create vapor flow problems of its own because of the temperature and pressure variations within the centrifuge. Pressure equalization lines were consequently installed between critical chambers of the centrifuge to alleviate internal flow of vapors. This produced an additional improvement in centrifuge performance and the catalyst specification of the overflow product was easily met.

After several weeks of satisfactory operation of the Merco pilot centrifuge, it was decided to proceed with the design of commercial-size centrifuges. A summary of the performance of the pilot centrifuge together with predicted performance for the commercial units is presented in Table 1.

Table 1. Performance of Pressurized Merco Centrifuges in Marlex Polyethylene Catalyst-Removal Service

Actual performance of pilot unit

Speed:	6650 rev./min.
G's:	4000
Nozzles:	12 No. 53 (drill size)
Feed temp:	300°F.
Pressure:	5 atm.

Feed rate, gal./min.	Overflow to underflow ratio	Catalyst content of overflow product, p.p.m.(*)
6	5	0.0— 8.0
4	10	0.0— 8.0
6	10	0.0— 8.0
6	13	8.0—20.0

Predicted performance of C-30 commercial centrifuge

Speed:	2500 rev./min.
G's:	3000
Nozzles:	20 No. 53 (drill size)
Feed temp:	300°F.
Pressure:	5 atm.
Separation efficiency:	Equivalent to pilot centrifuge operating with 9000 G's.

Feed rate, gal./min.	Overflow to underflow ratio	Catalyst content of overflow product, p.p.m.(*)
125	5	8
175	5	20

(*) Specification level is 8 p.p.m.

Design of commercial, pressurized centrifuge

The major problems involved in the design and construction of the large centrifuge were the seal, the flexible closure, and the pressure housing for the rotor.

Based on the performance of the single mechanical seal used in the pilot centrifuge, a double mechanical seal of conventional design was selected for the large centrifuge. No difficulty was experienced in adapting the seal to the centrifuge.

The design of a large flexible clo-

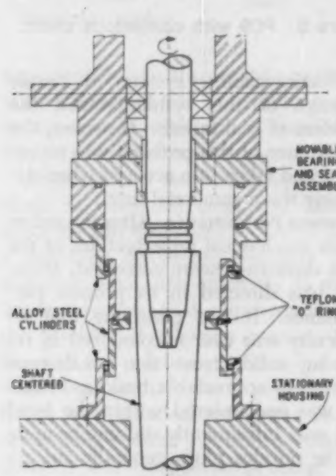

Figure 7. Flexible closure used in PC-30 centrifuge.

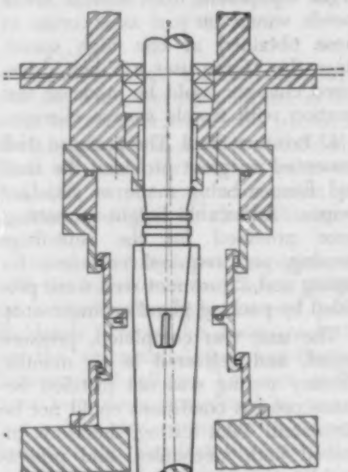

Figure 7a. Shaft swing to left in PC-30 centrifuge.

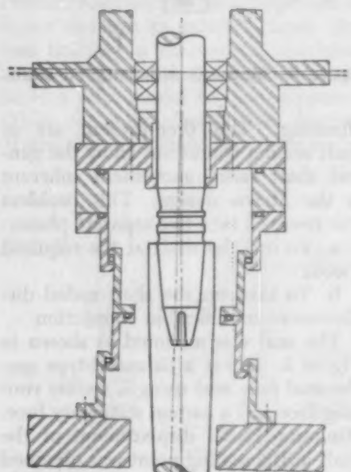

Figure 7b. Shaft swing to right in PC-30 centrifuge.

sure between the seal and the centrifuge housing was the greatest problem encountered. In order to reduce the chances of an unworkable design, two distinctly different types of closures were designed and tested simultaneously. An entirely new type of closure is shown in Figure 7 and Figures 7a and 7b illustrate how this closure accommodates radial displacement of the shaft. The other design consisted of a standard, single-convolution, flexible connection. The centrifuges were designed to accept either closure.

The flexible closure (Figure 7) proved to be practical and safe. This closure which used other than O rings, alloy steel rings, or cylinders had a high factor of safety because of the inherent strength of its components. It can readily be seen from Figure 7 that even in the event of O ring failure the opening through which high-pressure solvent vapors may escape to the outside is small. It is felt that the unique design of this closure which in case of failure results in leakage upwards or downwards but not outwards is a prime safety feature. The alternate closure also tested satisfactorily but was not used because it was more cumbersome and restraining.

Design of the pressure housing was complicated because of its intricate shape. Such structures are not covered by the ASME Code and it was therefore necessary to design the housing for three times its working pressure rather than one and one-half times. This resulted in a test pressure of 330 lb./sq. in. gauge and therefore extremely heavy components were required.

The upward pressure thrust on the bearing assembly was compensated for by springs which returned the load to the housing and yet allowed the free rotor movement of the Merco suspended-rotor design (Figure 1).

In addition to the seal, housing, and closure design, redesign of the following standard basic components of the large Merco machine were required:

a. Hoist column
b. Hoist piston and cylinder for lifting capacity
c. Radial arm for increased load-carrying capacity
d. Bearing housing for seal incorporation and thrust compensation
e. Rotor shaft for increased length

The completed machine was factory tested under closely simulated process conditions of temperature and pressure. During the trial which ran continuously for seven days, power requirements indicated that "vapor drag" on the rotor varied approximately as the fifth power of the rotor diameter. Based on these findings the units were equipped with a drive 50% larger than normal which would allow higher speed, if desired, at a future date.

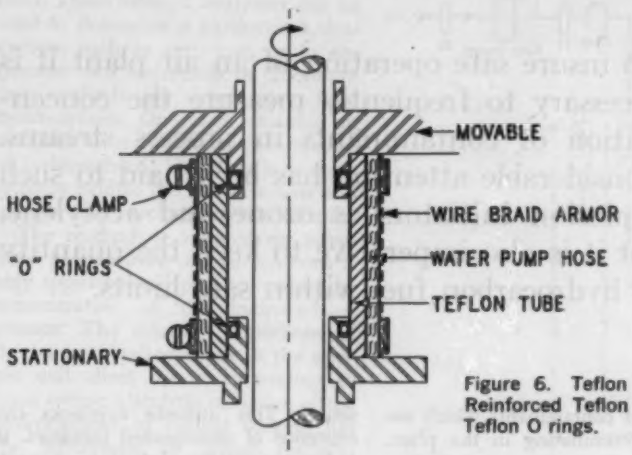

Figure 6. Teflon closure — Reinforced Teflon sleeve with Teflon O rings.

Throughout manufacture all components subject to speed and/or pressure were checked by X-ray and strain-gauge tests. A close-up of the PC-30 Merco centrifuge is presented in Figure 8.

Performance of centrifuge

The mechanical performance of the commercial-size centrifuges in production operations in several licensee plants of the Phillips polyolefin process has exceeded expectations *(7)*. In the initial phases of start-up it was found necessary to replace the synthetic rubber O rings in the flexible closure with rings of Teflon. The synthetic rubber O rings under constantly moving conditions tend to twist until the diameter is insufficient to seal. In addition, the substitution of Teflon O rings reduced or even eliminated the tendency of the rotor to develop a gyrating motion.

Performance of the mechanical seal has been excellent. The few seal failures that have occurred have resulted from operational upsets.

Erosive action has not been in evidence even in the bore of the underflow nozzles. It is anticipated that the replacement of major parts as a result of erosion will be a matter of operation for many years.

Although the importance of proper venting and equalizing the various chambers of the centrifuge housing had been discovered in pilot-plant work, the magnitude and need for proper control of these areas was found to be even more critical in the large centrifuges. In order to cope with the problems of vapor flow and the degassing of liquids, the speed of the rotor was reduced from that for which it was originally designed. This speed reduction yielded four results:

1. The magnitude, and therefore the effect, of vapor flow patterns were reduced.

2. Less heat was generated with a resultant decrease in the flashing tendency of the polymer solution.

3. The power requirements were significantly reduced.

4. Larger underflow nozzles could be used which virtually eliminated any plugging problems.

At no time during plant start-ups have the centrifuges caused plant shutdowns. Once on stream the centrifuges have operated continuously except for scheduled plant shutdowns. Maintenance shutdowns for the centrifuges are presently scheduled every three months with continuous operation during the interim period. It is expected that the frequency of maintenance shutdowns will be decreased as additional experience is gained.

Process performance has been better than predicted from pilot-plant operations. Overflow product is consistently produced with catalyst content below the specification value of 8 p.p.m. at feed rates as high as 150 gal./min.

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Presented at A.I.Ch.E. Salt Lake City meeting, September, 1958.

Continuous monitoring of HYDROCARBON CONTAMINANTS in low temperature air separation plants

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To insure safe operation of an air plant it is necessary to frequently measure the concentration of contaminants in process streams. Considerable attention has been paid to such explosion initiators as ozone and acetylene, but it is also imperative to keep the quantity of hydrocarbon fuel within safe limits.

IN RECENT YEARS there has been an increasing demand for large quantities of high purity oxygen and nitrogen. To meet this demand, many new low temperature air separation plants have been built. A large number of these new plants are located in industrial areas near chemical plants, oil refineries, and steel mills, where atmospheric pollution can be a serious problem. Because some of the contaminants present in industrial atmospheres are potential safety hazards when concentrated in liquid oxygen, there has been considerable emphasis on safe design and safe operation of air plants.

Several articles have been published recently *(1, 2)* which discuss principles of safe design and operation. A safe design is only the beginning of a safe plant. In addition, the plant must be operated in the safest possible manner. Two of the most important principles of safe operation are:

1. Keep the quantity of contaminants entering the plant to a minimum.
2. Prevent contaminants which enter from accumulating in the plant.

For an explosion to occur in an air plant, both oxygen and a fuel must be present, plus some means of initiation. Since oxygen must be present by the nature of the process, only the fuel and means of initiation can be controlled. All initiators or suspected initiators, such as acetylene, ozone, and oxides of nitrogen, should be kept at very low levels. However, it is also imperative to keep the quantity of fuel within safe limits since all possible means of initiation may not be known. To control only the concentration of initiators such as acetylene and to ignore the concentration of hydrocarbon fuel is fundamentally unsound. This attitude overlooks the existence of unsuspected initiators. If a large quantity of fuel is present, there is the remote possibility that it may be detonated by some unsuspected means of initiation even though no acetylene is present. For effective elimination of explosion hazard, it is necessary to control the concentration of both hydrocarbon fuel and all known or suspected initiators.

To insure safe operation of an air plant, it is necessary to frequently measure the concentration of contaminants in various process streams. For many years operators had to rely entirely on intermittent chemical testing, which was both time consuming and expensive and which resulted in considerable delay before the results were known. With recent advances in instrumentation, it is now possible to monitor all hydrocarbon fuels and some initiators on a continuous basis.

One of the most important developments has been the use of nondispersive infrared analyzers for measuring hydrocarbons at very low concentra-

ACKNOWLEDGMENT

Clyde McKinley and his associates of Air Products, Inc., were helpful in early development work on the infrared analyzers.

Figures 1, 2 & 3. In Figure 1 a simplified flow diagram of a Sun Oil Company Air Plant shows the exact location of hydrocarbon analyzers. Figure 2 is an infrared analyzer and related sampling equipment for measuring total hydrocarbon concentration in four process streams. Figure 3 shows catalytic oxidation chambers used to convert hydrocarbon contaminants to carbon dioxide which is determined by the infrared analyzer.

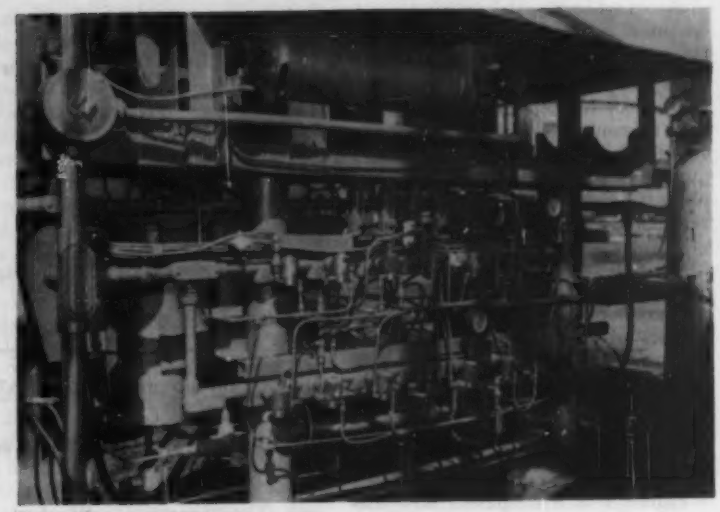
Figure 2

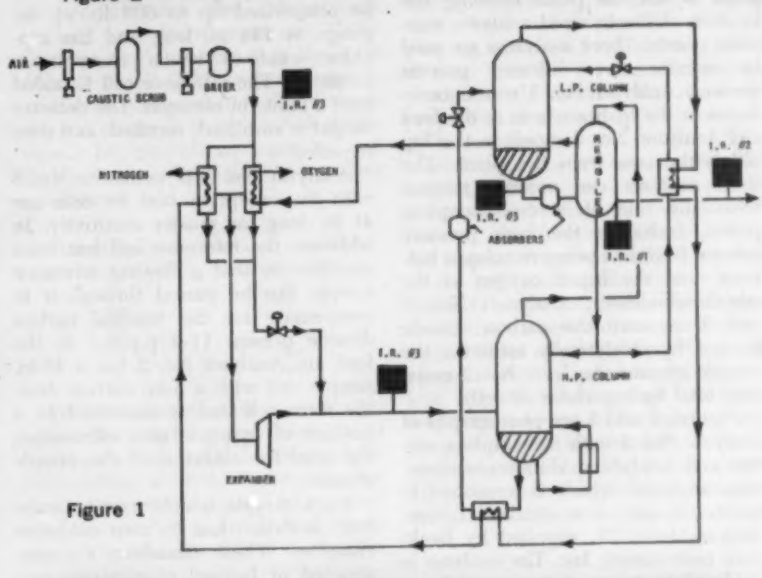

Figure 1

tions. These infrared analyzers can be used to determine a particular hydrocarbon, such as acetylene, or to determine total hydrocarbons. There are two methods for determining total hydrocarbons. One is to sensitize an analyzer to a representative mixture of hydrocarbons. The other is to catalytically oxidize the hydrocarbons and monitor the resultant carbon dioxide.

The reading of an analyzer sensitized to a mixture of hydrocarbons is only approximately proportional to the concentration of the hydrocarbons present. The relative proportions of the various hydrocarbons in the sample will affect the scale reading to some extent. Catalytic oxidation of the hydrocarbons to carbon dioxide has the advantage of giving readings which are proportional to the weight of hydrocarbons present. It is also a more sensitive method since carbon dioxide is a much stronger absorber of infrared radiation than hydrocarbons, and since each mol of hydrocarbon heavier than methane produces two or more mols of carbon dioxide. If a sample stream contains a few parts per million of carbon dioxide before oxidation, it can be compensated by passing a portion of the unoxidized sample through a reference cell in the analyzer. In this way, only the increase in carbon dioxide concentration resulting from oxidation is measured.

A total hydrocarbon analyzer is not effective for controlling acetylene contamination in an air plant. Since dangerous acetylene concentrations are several orders of magnitude lower than total hydrocarbon concentrations, an acetylene build-up cannot be detected

continued


Figure 3

continued

by a hydrocarbon analyzer. In most areas frequent laboratory testing is satisfactory for determining the acetylene concentration in the liquid oxygen. However, in areas with significant quantities of acetylene in the atmosphere, a continuous acetylene analyzer should be considered.

Sun Oil Installation

At the Sun Oil Company air plant at Marcus Hook, Pennsylvania, extensive use of infrared analyzers is made to monitor total hydrocarbons in various process streams. The air plant produces about 290 tons/day of high purity nitrogen for ammonia synthesis and 90 tons/day of gaseous 95% oxygen.

Figure 1 is a simplified flow diagram of the air plant showing the location of the infrared analyzer sampling points. Three analyzers are used to monitor five different process streams. Analyzer No. 1 continuously monitors the hydrocarbons in the feed air. Analyzer No. 2 monitors the liquid withdrawn from the plant. The third analyzer can monitor streams from any one of several sampling points, including the high pressure column feed, low pressure column bottoms, and the liquid oxygen in the reboiler-condenser. Analyzers Nos. 1 and 3 measure the carbon dioxide formed by catalytically oxidizing the sample streams. Analyzer No. 2 measures total hydrocarbons directly.

Figures 2 and 3 are photographs of analyzer No. 3 with its sampling system and catalytic oxidation chambers. This analyzer, which is sensitized to carbon dioxide, is a standard Liston-Becker Model 21, supplied by Beckman Instruments, Inc. The analyzer is enclosed in an explosion-proof housing since it is located in the plant

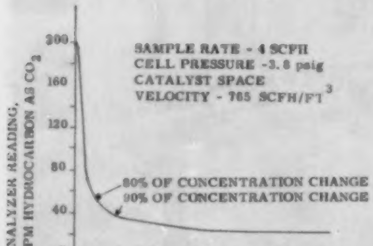

Figure 5. Response of a catalytic oxidation chamber and infrared analyzer to a change in sample stream. The same catalytic oxidation chamber being used for both samples.

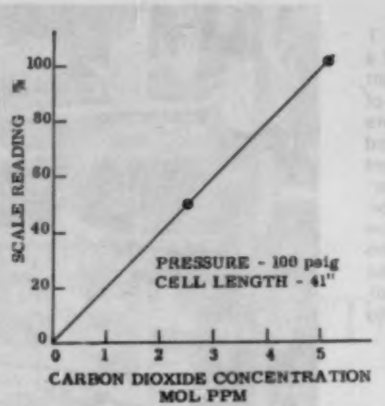

Figure 4. Calibration curve for an infrared analyzer.

area. The absorption cell, which can be pressurized up to 600 lb./sq. in. gauge, is 13⅜ in. long and has sapphire windows which transmit to about 6μ. The reference cell is sealed with a filling of nitrogen. The detector output is amplified, rectified, and then recorded.

Analyzer No. 1 is similar to No. 3 with the exception that its cells are 41 in. long for greater sensitivity. In addition, the reference cell has been modified so that a flowing reference sample can be passed through it to compensate for the residual carbon dioxide present (1-2 p.p.m.) in the feed air. Analyzer No. 2 has a 35-in. sample cell with a 5-in. carbon dioxide filter cell and is sensitized to a mixture of hydrocarbons, eliminating the need for oxidation of the sample stream.

Each sample which requires catalytic oxidation has its own oxidation chamber. These chambers are constructed of Inconel to eliminate carbon dioxide contamination which results from the use of steel. They are filled with about 9 cu. in. of Baker Platinum Division (Engelhard Industries) Type F pelleted catalyst. The oxidation chambers are maintained at about 900°F. with special nickel-plated heaters coiled around the chambers. These heaters can safely operate in Class I, Group D, Division 2 areas. The catalyst chambers are insulated with 4 in. of high temperature insulation covered with sheet metal. An iron-constantan thermocouple in each catalyst bed is used to measure the temperature.

The sampling systems for the analyzers were carefully designed to insure minimum lag time with maximum flexibility and simplicity of operation. The sampling points for the liquid streams are located as close to the outside of the cold box as possible to keep the length of the sample lines to a minimum. To further reduce lag time, the liquid samples are vaporized as soon as they leave the cold box. Two types of vaporizers have been used successfully. The simplest type consists of a coil of ¼-in. tubing immersed in a bath of boiling water. The second type consists of a small electrically heated stainless steel vessel. By maintaining a large excess heat input, the walls of the vessel are kept hot enough to completely vaporize the liquid as it enters the vessel.

The multipoint analyzer has a specially designed, versatile sampling manifold. The flows of the sample streams and calibrating gases to the analyzer are controlled by solenoid valves operated from the control room. The sample streams continuously flow through their individual oxidation chambers, with only the sample being monitored passing through the analyzer. Those oxidized streams which are not flowing through the analyzer are vented directly to the atmosphere. All sample lines to the analyzers contain sintered steel filters with 20-μ porosity.

Evaluation of the analyzers and oxidation catalyst

Infrared analyzers Nos. 1 and 3 have been calibrated over a range of carbon dioxide concentrations using reference mixtures whose compositions were known from chemical analysis. The full-scale ranges of the analyzers are varied by changing the sample pressure or amplifier gain setting. With a 41-in. cell at a pressure of 100 lb./sq. in. gauge, the full-scale chart reading corresponds to 5 p.p.m. carbon dioxide and the calibration curve is linear. (See Figure 4.) The limit of detectability is about 0.2

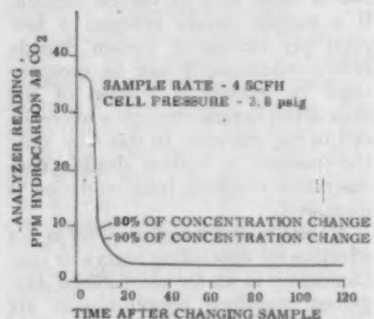

Figure 6. Response of infrared analyzer #3 to a change in sample stream. Each stream passing through a separate catalytic oxidation chamber.

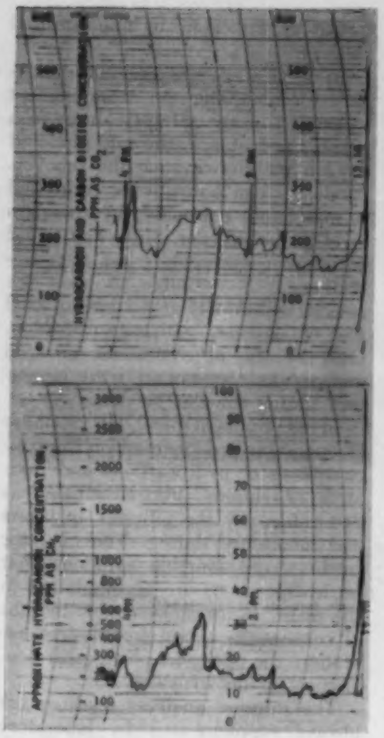

Figure 7. Comparison of the response of an infrared analyzer sensitized to hydrocarbons with the response of a catalytic oxidation chamber and infrared analyzer sensitized to carbon dioxide.

p.p.m. At atmospheric pressure, full-scale readings of 50 to 200 p.p.m. can be obtained with linear calibration curves. At higher concentrations the calibration curve becomes nonlinear because of excessive absorption. Since it was desired to use analyzer No. 3 for samples containing up to 500 p.p.m., a standard 13⅝-in. cell was used. This cell gives good linearity over full-scale ranges of 60 to 600 p.p.m.

Analyzer No. 2 is calibrated using a mixture of methane in nitrogen. The full-scale reading is 3000 ppm. methane and the calibration curve is nonlinear. A linear calibration curve could be obtained by shortening the cell length.

The effectiveness of the oxidation catalyst was studied by passing known mixtures of methane in carbon dioxide-free air over the catalyst and through an infrared analyzer. Methane was used because it is the most difficult of all light hydrocarbons to oxidize. A comparison of the methane concentrations in the blends as determined by gas chromatography and the analyzer readings showed excellent agreement.

Table A

Methane in blend, p.p.m. CH_4	Analyzer reading, p.p.m. CO_2
24	24
30	32
30	31
50	51
87	88

To determine whether there was an upper limit to the concentration of methane which could be oxidized by the catalyst, a mixture containing approximately 6000 p.p.m. was passed over the catalyst under normal conditions. The concentration of methane in the exit gas, as determined by gas chromatography, was less than 1 p.p.m.

To learn whether lubricating oil would deactivate the catalyst, some oil in a gas stream was introduced into the catalyst chamber for a short period of time. The expected formation of large concentrations of carbon dioxide occurred for a while, but there was no indication of any loss of catalytic activity.

During early work with the oxidation catalyst and infrared analyzer, it was found that the catalyst is an excellent adsorbent for carbon dioxide. Fresh catalyst, when placed in a chamber at a temperature of about 950°F. and purged with pure oxygen, gives off several hundred parts per million of carbon dioxide for nearly a week before the blank valve drops to zero. After subsequent exposures to the atmosphere, the catalyst again shows high carbon dioxide values on purging, although for a shorter period of time than for the initial clean-up.

Another indication of the adsorbent properties of the catalyst was noted. A known mixture of methane was passed over the catalyst at 950°F. long enough to give a constant carbon dioxide value. When the catalyst temperature was dropped by about 50°F., the apparent carbon dioxide content of the exit gas first dropped to zero. As the temperature was held constant, the carbon dioxide reading returned to its original value. When the temperature was raised 50°F., the carbon dioxide reading first increased and then returned to the original value at the higher temperature. It seems clear that an equilibrium is established at each temperature between the carbon dioxide in the gas stream

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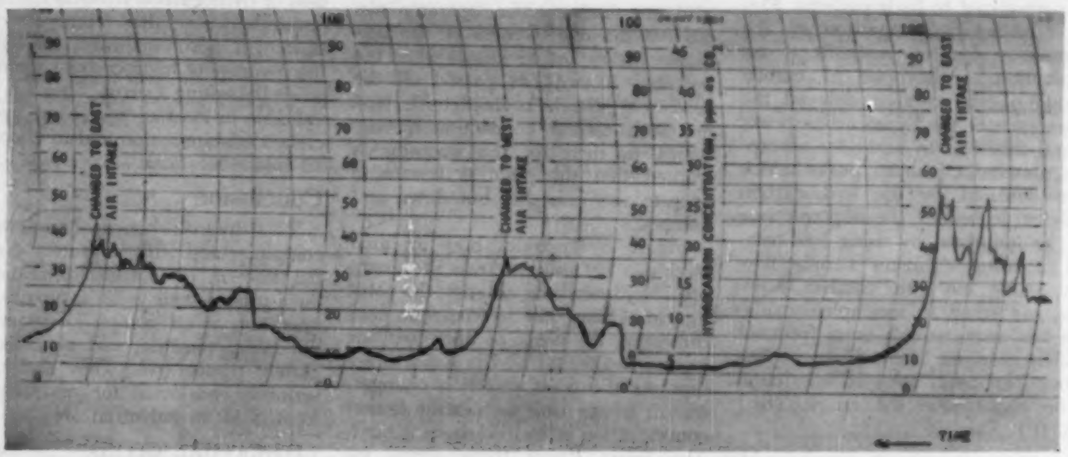

Figure 8. Illustration of how feed air infrared analyzer is used to minimize hydrocarbon concentration in feed air entering cold box.

. . . the operator is warned that the plant is unsafe to operate and must be shut down and dumped.

continued

and that adsorbed on the catalyst. For this reason the oxidation temperature is held within fairly narrow limits (±10°F.) although the exact value is not important.

Measurements have been made to determine the time required for carbon dioxide in a sample to reach equilibrium with that on the catalyst. A sample stream of known methane concentration was passed over the oxidation catalyst for several hours to be certain that equilibrium was achieved. The sample was then replaced by another stream of known concentration and the time required to reach equilibrium was measured. Figure 5 shows the results of these experiments. Since the time required to achieve 90% of the change is almost 10 min., it is undesirable to use one catalytic oxidation chamber for more than one sample. If, however, each sample stream has its own oxidation chamber, the lag time when changing samples is reduced to only that time required to purge the analyzer sample cell. Figure 6 shows a lag time of considerably less than one minute when separate oxidation chambers are used.

The response time of the catalyst to changes in hydrocarbon concentrations in a sample stream has also been studied. Part of a sample stream containing some carbon dioxide and about 200 p.p.m. hydrocarbons was passed over catalyst and through an analyzer sensitized to carbon dioxide. Another part of the same stream was simultaneously passed directly to the analyzer sensitized to hydrocarbons. Figure 7 shows a comparison of the response of the two methods of determination. Adsorption of carbon dioxide on the catalyst delayed the appearance of the hydrocarbon peaks several minutes. In addition, adsorption rounded off sharp peaks which were detected by the hydrocarbon analyzer. If desired, the response time can be improved by using less catalyst or using a higher sample flow rate. Using too little catalyst, however, can result in incomplete oxidation and may require more frequent catalyst changes. The maximum space velocity for fresh catalyst was found to be about 6000 std. cu. ft./(hr.)(cu. ft.).

Analyzer performance in the plant

During the first two years of operation, there has been no serious maintenance problem on any of the analyzers. Almost all of the maintenance which has been required has been related to the infrared source assembly. The most frequent trouble has been dirty contacts which are easily cleaned. Several of the chopper motors and bearings have also required some attention. Dirt in the sample stream has caused some trouble, requiring cleaning of the sample cells and filters on two occasions. Only a few hours a month of servicing are required to keep the analyzers in good working condition. By well-planned preventive maintenance and by stocking important spare parts, it has been possible to almost entirely eliminate instrument failures.

In addition to maintenance, the zero and full-scale span of each analyzer are checked three times a week. These checks take about one hour per week for each analyzer. Both the zero and span drift have been less than the maximum guaranteed by the manufacturer. Any large or erratic changes in the zero or gain settings indicate trouble, which is immediately investigated. Once a month the catalyst activity of each of the chambers is checked using a standard methane blend. This check requires about an hour for each chamber. No catalyst deactivation has been detected.

Value of infrared analyzers

The value of infrared analyzers as aids to safe operation of air plants is immeasurable. They warn an operator of potentially hazardous conditions and enable him to take quick corrective action. The operator can observe the effectiveness of the corrective action and he knows when the potential hazard has passed. If the corrective action is ineffective and the hydrocarbon concentration continues to increase, the operator is warned that the plant is unsafe to operate and must be shut down and dumped.

Figure 8 illustrates how an analyzer can be used to keep the quantity of hydrocarbons entering the plant to a minimum. The hydrocarbon concentration at each of the two air intakes is affected by the wind direction. As the wind direction changes, the air intake which gives the lowest concentration of hydrocarbons is used. The figure shows three actual instances when the hydrocarbon concentration in the feed air was reduced about 75% by using the proper air intake as indicated by the infrared analyzer.

Infrared analyzers are also necessary for obtaining the most efficient utilization of the safety features in a plant. For instance, the rate of liquid oxygen withdrawn from the reboiler-condenser can normally be controlled to maintain a reasonable hydrocarbon level in the reboiler. Since any liquid withdrawn represents a loss of refrigeration, it is desirable to keep the rate of withdrawal at the lowest level that is consistent with safe operation. Only by use of continuous infrared analysis in conjunction with laboratory testing can this be done.

In the Sun Oil plant, every phase of operation is dependent on the concentration of hydrocarbons and initiators in various process streams as determined by the infrared analyzers and laboratory testing. The analyzer readings are tangible evidence that no hydrocarbons are accumulating in the plant. As a result of many months of continuous, almost trouble-free operation, the operators place great confidence in the analyzers.

The infrared analyzer readings are always supplemented by laboratory testing. Acetylene and nitrogen oxides are determined one or two times a day. Total oxidants (ozone) are measured twice a week. Complete hydrocarbon analyses by carbon number of various streams are made three times a week. The methods used are gas chromatography for methane and a combination of low temperature freeze-out and mass spectrometry for ethane and heavier.

The hydrocarbon analyzers are also valuable research tools for studying such problems as distribution of hydrocarbons in an air plant, effectiveness of hydrocarbon removal facilities, optimum regeneration temperature for silica gel adsorbers, and measuring the quantity of hydrocarbons removed when defrosting a plant. They are also valuable in locating sources of hydrocarbon contamination and in choosing air intake locations.

Conclusion

Total hydrocarbon analyzers, when complemented with laboratory testing for known or suspected initiators, have proven their value as aids to safe operation of air plants. They are dependable, versatile, and almost completely trouble-free. They should be seriously considered for any air plant located in an industrial area.

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FRACTURING under explosive loading

The mechanics and physics of the fracturing of metal under impulsive loads is of prime importance to engineering safety. Here, fracture patterns are studied to demonstrate significant features of the fracture process.

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Marked differences exist between the fracture phenomena associated with impulsive loads and those associated with static loads *(1, 2)*. Under static loads the stresses and the strains will be distributed throughout the entire body that is being loaded so that every part of the body has an opportunity to participate in the initiation of fractures. Once a fracture has been initiated statically, local stress concentrations associated with propagation of the fracture then become important. Under impulsive loads, rapidly changing and highly localized stresses and strains can exist so that fractures may occur in one part of the specimen quite independently of what happens in another part. Design criteria applicable to static cases frequently cannot be applied when impulsive loads are involved.

This paper describes several examples of the fractures which were produced in metal plates, rods, tubes, and various other kinds of metal objects when subjected to the high and rapidly applied stresses that are generated by explosive charges. The examples can be considered as typical of the types of fractures that are frequently encountered and their dynamics of formation represent some of the more common transient situations that can lead to fracturing.

Loading generated by an explosive charge

In the systems considered here explosive charges were used to produce the impulsive load; in each case the explosive was placed in intimate contact with one or more surfaces of the metal object. Sketches of a number of the metal-explosive systems that have been studied are shown in Figure 1. The explosive in each case was Composition C-3 which has about the same consistency as plasticine and can be modeled with the hands into almost any shape desired. An electric detonator was used to initiate each of the explosive charges.

A disturbance will be induced in the metal body as the result of detonation of the explosive. The pressure vs. time curve at a particular point on the loaded surface of the body depends to a large extent upon the geometry of the metal-explosive system. In a particular system, the shape of the curve can vary markedly from point to point on the surface although

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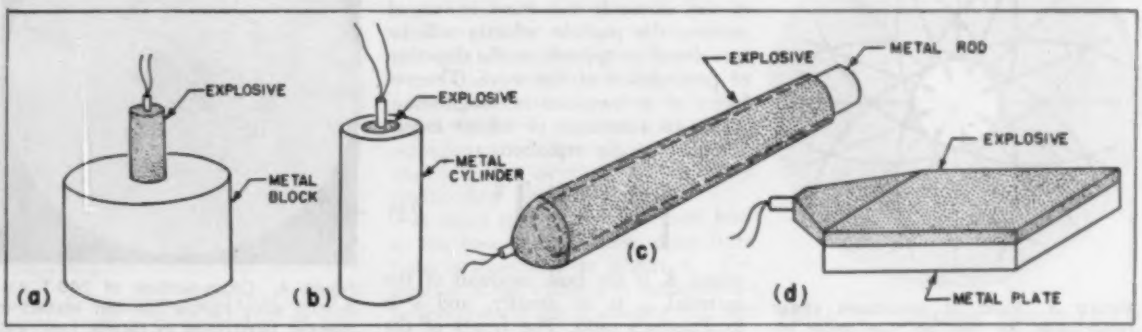

Figure 1. Representative metal-explosive systems.

Fracturing

continued

the initial maximum pressure will probably be about the same at all points. Since the metal is not rigid, it will react to the pressure of the explosive. The nature of the disturbance which ensues will depend in a complicated and not completely understood way on the physical properties of the metal under the unusual conditions that exist at the explosive-metal interface as well as on the geometry of the metal-explosive system.

Extrapolation of data on the compressibility of metals *(3)* suggests that the pressure at the interface, as

Table 1. Critical differential particle velocities and associated critical-normal-fracture stresses

Material	Differential particle velocity needed to cause fracture (ft./sec.)	Associated critical-normal-fracture stress (lb./sq. in.)
24S-T Aluminum Alloy	202	140,000
Copper (annealed)	264	410,000
Brass	216	310,000
1020 Steel (annealed)	84	160,000
4130 Steel (annealed)	235	440,000

viewed from within a steel plate, is about 280,000 kg./sq. cm. The initial velocity of the surface of a steel plate is about 690 m./sec. Corresponding figures for lead are 270,000 kg./sq. cm. and 790 m./sec. The pressure rises instantaneously (in less than a fractional part of a microsecond) to its maximum value, and it then begins to decay. In general, its duration will not exceed a few microseconds. The disturbance will move through any common metal with a velocity in the neighborhood of its

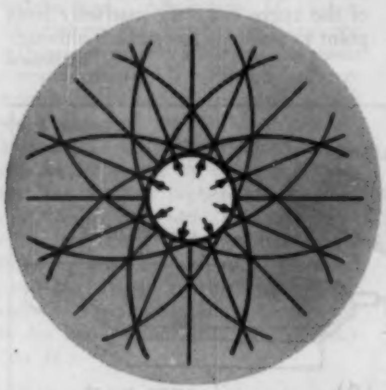

Figure 3. Field of maximum shear trajectories for circular hole under internal pressure.

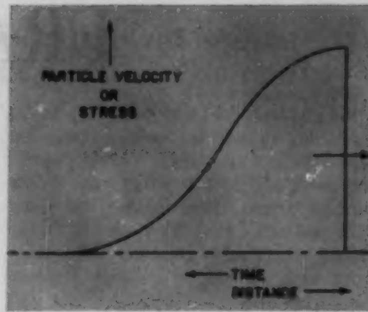

Figure 2. General profile of transient disturbance generated by an explosive charge.

elastic dilatational wave velocity. Thus, the disturbance appears in the metal as a sharp-fronted transient wave whose length in most metals will be of the order of inches or fractions of an inch.

At some distance from the area of application of the explosive the disturbance can be considered to be essentially elastic since it is in the nature of an unloading wave. As a first approximation its form can be taken as that shown in Figure 2, the curve of which may be thought of as representing any one of the following: (1) a spatial distribution of particle velocity, (2) a spatial distribution of stress, (3) a temporal distribution of particle velocity, (4) a temporal distribution of stress. The shape of the curve will be substantially the same whichever combination is chosen, for, as long as the disturbance is elastic, stress and particle velocity are related through the equation

$$\sigma = \rho c v \qquad (1)$$

where σ is the stress, ρ is the density of the material, c is the velocity of propagation of the disturbance, and v is the instantaneous particle velocity at a point within the disturbance. For longitudinal waves, the particle velocity will be normal to the wave front. In the case of a compressional wave, particle velocity will be in the same direction as that of propagation of the wave. If the wave is one of tension, the particle velocity will be in a direction opposite to the direction of propagation of the wave. The velocity of propagation of longitudinal waves in a medium of infinite extent is given by the equation

$$c = \left[\frac{3K\ (1-v)}{\rho\ (1+v)}\right]^{1/2} \qquad (2)$$

where K is the bulk modulus of the material, ρ is its density, and v is its Poisson's ratio. The fronts of the pulses being considered propagate with approximately the velocity given by Equation (2).

In general, the shape and the intensity of a disturbance will change continually as the disturbance moves through a body. Radial, tangential, axial, and shear stresses are likely to develop in disturbances having nonplanar fronts (4).

When the pulse strikes a free surface or, indeed, any discontinuous boundary, it will be reflected. The simplest situation occurs if the wave strikes the surface normally. If the incident pulse is compressive, a tension wave will be reflected and vice versa. After reflection, the instantaneous value of the net stress at each point will be the sum of the stresses in the incident and reflected longitudinal waves. The surface will remain stress free at all times. When an elastic pulse strikes a free surface obliquely, the relationships which describe the reflection of the pulse become quite complicated. In general, an elastic pulse of a longitudinal type striking a free surface obliquely will generate reflected waves of both longitudinal and shear types.

Fracturing associated with trajectories of maximum shear

From a macroscopic point of view, the fractures that occur under impulsive loading fit into the two categories: shear fractures and tensile fractures. A shear fracture is a fracture that follows a maximum shear trajectory, and a tensile fracture is one that is perpendicular to a principal stress. Fields of maximum-shear trajectories are commonly used in discussions of the failure under static loads of massive structures such as foundations, dams, and roadways. Fields of maximum shear trajectories can be constructed if the distributions of principal

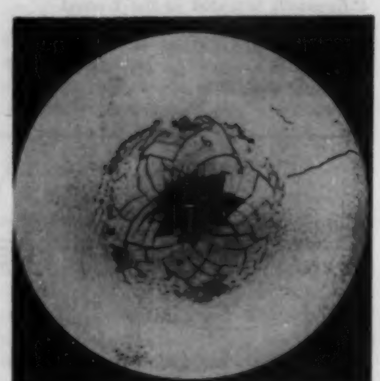

Figure 4. Cross-section of 24S-T aluminum alloy hollow cylinder loaded in manner illustrated in Figure 1(c). (¾ in. I.D., 1-in. wall, ⅛ in. explosive.)

stresses within the body are known. An example of a field of shear trajectories is shown in Figure 3. This is for a case where the problem can be reduced to a two dimensional one. In such a case there will be two mutually orthogonal trajectories of maximum shear stress at each point in the body. The trajectories are continuous lines without breaks. When an elastic body is strained beyond the elastic limit, failure lines are often observed to follow these trajectories. The occurrence of "Luder's" lines in mild steel is an example of such failure.

Numerous examples of fractures that follow shear trajectories have been observed in metal specimens that were loaded impulsively. One of the most interesting cases has been that in which the outside of a thick-walled hollow cylinder of 24S-T4 aluminum alloy was coated with a thin layer of explosive, Figure 1(c). A cross-sectional view of the recovered cylinder is shown in Figure 4. In this case, the thickness of the explosive was ⅛ in., the wall thickness of the tube 1 in., and the I. D. ⅜ in. Particle motion resulting from detonation of the explosive is more or less radially inward. The pattern of fractures is seen to correspond closely to the theoretical pattern of shear trajectories shown in Figure 3. Mild steel cylinders, when loaded in the same way, develop a pattern of "Luder's" lines that is similar to the fracture pattern in the aluminum alloy.

Professor Bridgman has shown (5) that under high hydrostatic pressures tensile fracturing occurs with great difficulty but that shear fracturing is unaffected by the pressure. A similar observation has been made in the case of impulsive loading. If, for example, a thick-walled hollow cylinder is internally loaded with explosive, Figure 1(b), two basic types of fractures are observed: shear fractures that lie close to the interior surface of the cylinder and tensile fractures that extend radially outward. Shear fracturing is confined to the interior surface with the fractures oriented at an angle of about 45 degrees to the circumference. An example of such fracturing is shown in Figure 5 where a 9-in. O.D. mild steel cylinder has been cross-sectioned and etched. The depth to which the shear fracturing extends is about ¼ in. and corresponds closely to the depth to which heavy plastic flow occurs.

A series of events which could lead to the formation of these shear fractures is illustrated in Figure 6. The interior of the cylinder is tremendously compressed but fracturing will not occur because such fracturing may

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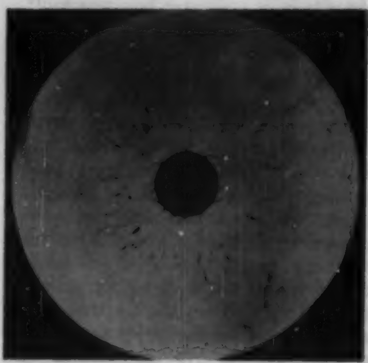

Figure 5. Cross-section of mild steel cylinder showing fractures resulting from internal loading (1-in. I.D., 4-in. wall).

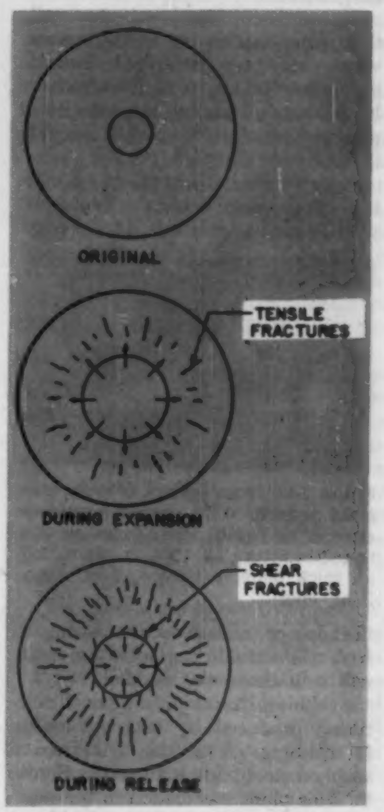

Figure 6. Sketches illustrating series of events leading to generation of fractures within thick-wall cylinders of type shown in Figure 5.

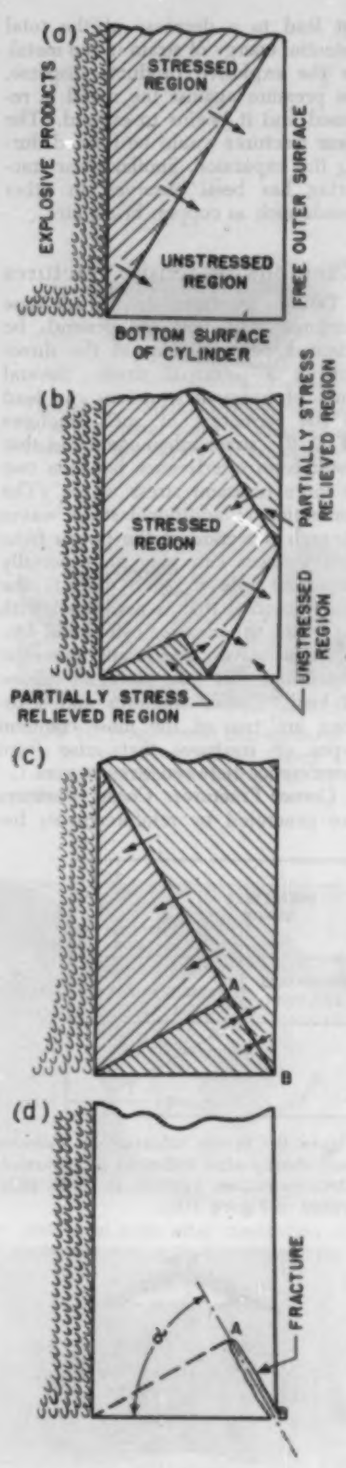

Figure 7. Qualitative aspects of the propagation, reflection and interaction of stress waves in a 90-degree corner.

continued

not lead to a decrease of the total potential energy of strain in the metal. As the explosive products disperse, the pressure against the metal is released and it begins to expand. The shear fractures would be formed during this expansion. Similar shear fracturing has been observed in other metals such as copper, brass, etc.

Examples of tensile fractures

Tensile fractures are brittle-type fractures that will, in general, be oriented perpendicular to the direction of a principal stress. Several kinds of transient situations can lead to the formation of such fractures (*1, 2, 6*): stress inhomogeneities that result from interference between two or more transient stress waves (The generation of additional stress waves through reflection of the pulses from free surfaces can play an especially important role in such cases.); the lateral motion that is associated with divergent spherical or cylindrical longitudinal waves; and large volumetric expansions that take place on release of load. Corner fractures and scabbing are two of the most common types of fractures that arise from interference between stress waves.

Corner Fractures. Corner fractures are generated by reinforcements between two or more release (or tension) waves that eat in simultaneously from two or more free surfaces. The material fractures because of a highly localized stress concentration that results from the division and subsequent reflection of a single compressional wave into two tensile waves on striking the two inclined free surfaces. Consider the situation shown in Figure 7. A compressive longitudinal disturbance is entering a 90-degree corner. As the incident wave strikes the two free surfaces, release waves propagate back into the compressed region. The release waves leave behind them partially stress-relieved regions which will be in a state of reduced compression. Eventually the fronts of the two release waves will meet. Encounter will take place along the line AB. A high tensile stress will exist along this line and as a result, fracturing may occur.

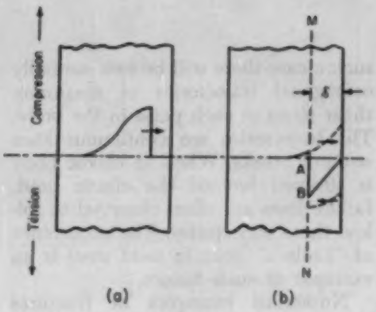

Figure 10. Stress distribution near free surface of plate of finite thickness and infinite lateral extent. (a) before reflection, and (b) shortly after reflection of transient disturbance.

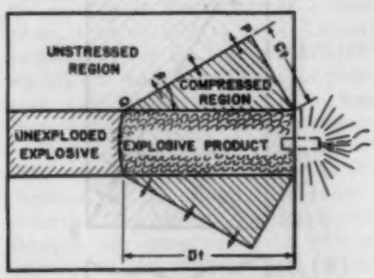

Figure 8. Stress situation in cylinder wall shortly after initiation of explosive. Metal-explosive system is that illustrated in Figure 1(b).

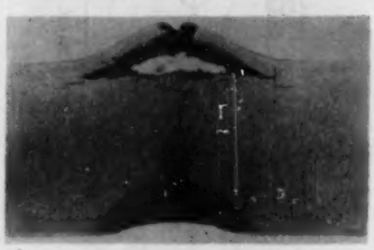

Figure 9. Cross-section of mild steel plate showing scabbing. (Metal-explosive system is that of Figure 1(a): 5 in. in diam. by 2-in. thick plate; charge 1½ in. diam. and 2 in. long.)

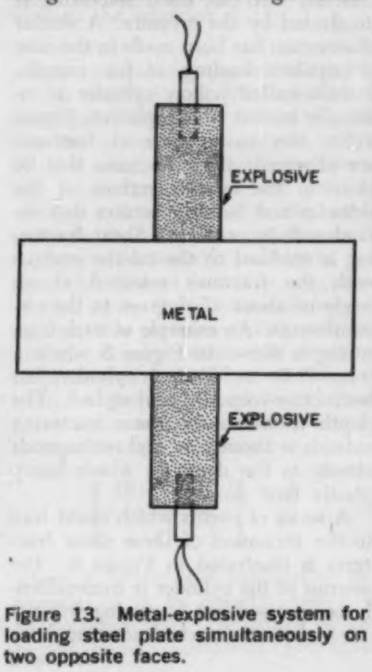

Figure 13. Metal-explosive system for loading steel plate simultaneously on two opposite faces.

Fractures in many different types of systems originate in the foregoing described manner. Such fracturing is, for example, extremely important in connection with studies of the comminution of brittle solids or in the fracturing of glass under impact loading.

A typical example of a corner fracture is the conical surface of fracture that is generated at the base of a thick-walled explosive filled cylinder, Figure 1(b), when the explosive is detonated at the opposite end (7). The stress situation in the cylinder shortly after initiation of the explosive is shown schematically and much simplified in Figure 8. The front of the transient disturbance *PQ*, will be inclined at an angle β to the axis of the cylinder. The sine of this angle will be given by the ratio: velocity of propagation of the disturbance divided by detonation velocity of the explosive. The wave will eventually find itself trapped in the lower corner of the cylinder as shown in Figure 7 and a conical surface of fracture will be generated.

It has been found experimentally that cylinders fracture in the manner which has been described; and, in fact, observed angles of fracture have been used to compute the velocity of propagation of stress waves in cylinders of several metals (7).

An extreme but important example is the zero degree corner, i.e., a flat plate loaded impulsively on the edge.

Figure 14. Cross-section of mild steel plate loaded with contact explosive charges on two opposite faces as illustrated in Figure 13. (5½ in. diam., 2½ in. thick plate; explosive, 1-in. diam., 2 in. long).

Because of release waves eating in from the outside surfaces, the plate will split down the middle.

Scabbing. A common type of fracturing produced by transient pulses is scabbing. A section cut from a scabbed steel plate is shown in Figure 9. This plate was loaded in the manner shown in Figure 1(a). Scabbing, sometimes called spalling, is usually taken to mean the fracturing of a body near one of its free surfaces

which is relatively far removed from the area of application of the pressure impulse. Fracturing of this type was first described by Hopkinson many years ago and is sometimes known as a Hopkinson fracture (*8*).

The mechanics of scabbing can be treated qualitatively as follows: consider a laterally infinite slab of finite thickness and assume a perfectly elastic plate material. Suppose that the pressure pulse is of the form shown in Figure 2, that is, the pressure rises instantaneously and then begins to decay. When the disturbance strikes the free boundary of the plate, it will be reflected as a tension wave. The incident compression wave and its reflected tension counterpart will interfere. The resultant distribution of stress within the plate at some time during reflection of the wave will be that shown in Figure 10. The tension *AB* will increase as the reflected wave moves to the left. If at some point the metal can no longer support this tension, it will fracture and a scab will fly off. The thickness of the scab will be equal to one-half the distance within the wave that corresponds to a decrease in stress equal to the stress at which the material fractures. This stress is called its critical-normal-fracture stress, σ_c.

Studies (*9, 10*) of the scabbing of metal plates have shown that the two factors that are of most importance as regards scabbing are (1) the *shape* of the stress wave, and (2) the critical-normal-fracture stress of the material. The latter is characteristic of the material acted upon although its value may be influenced by the conditions of loading and the state of stress in the body at the instant fracturing occurs.

The strong dependence that the location of the scab has on the shape of the stress wave is perhaps best illustrated by some examples of scabbing of flat mild steel plates that were explosively loaded in the manner shown in Figure 1(d). The plates in the test ranged in thickness from ¼ to 2 in., the explosive charges were ⅛ and ¼ in. thick.

The results are shown in Figure 11. The most interesting things shown by the two curves are (1) that the thickness of the scab increases rather than decreases with plate thickness, and (2) that, under some conditions, a ⅛ in. layer of explosive can produce a thicker scab than a ¼ in. layer. Qualitatively, the curves might be expected to run as they do. Decrease in steepness of the stress-time curve behind the wave front with increasing plate thickness will cause increasingly thicker scabs to form. The pulse will be more sustained and the initial pressure somewhat higher for the thicker charge; hence, when the plate is thin, the thickness of the scab generated by the ¼ in. layer of explosive will be greater than that generated by the ⅛ in. layer.

Multiple scabbing occurs when the level of stress within the wave is more than double the critical-normal-fracture stress of the material. In such cases several juxtaposed and parallel scabs are generated within a single plate. These arise in the following way: assume that the first scab is generated instantaneously in the manner described above. The remainder of the wave will suddenly find itself impinging on a freshly created free boundary surface. The result will be the formation of another scab. This process will repeat itself until the

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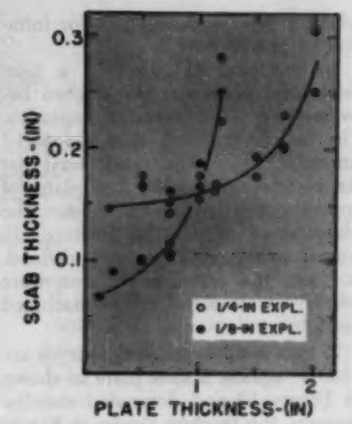

Figure 11. Dependence of scab thickness on plate thickness for two thicknesses of explosive. Plates were mild steel and loaded in manner of Figure 1(d).

Figure 12. Metal-explosive system in which metal plate is sandwiched between two layers of explosive.

Figure 15. Fragmented steel rod loaded by coating the surface with a thin layer of explosive in manner of Figure 1(c). Rod in background is similar to original specimen (1-in. diam. rod, ⅛ in. explosive).

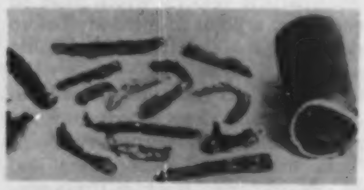

Figure 16. Fragmented thin-walled steel tube loaded in manner of Figure 1(c) (1-in. I.D., 1/16 in. wall tube; ¼ in. explosive).

Figure 17. Sectioned 2-in. diam., ½ in. wall steel tube after detonation of ¼ in. (left tube) and ⅛ in. (right tube) explosive charge on outside surface. Loaded in manner of Figure 1 (c). Original tube in center.

Fracturing

continued

stress level of the wave has been reduced to a value less than σ_c. In Figure 9 a second scab is just beginning to form.

Considerable experimental work has been directed toward obtaining quantitative data that relate to scabbing. Most of the data have been obtained from a modified Hopkinson-bar-type of experiment. Specifically, the intensities and durations of the transient pulses that produce the scabs have been determined and these have been related to observed scab thicknesses for several different metals. Values of the critical-normal-fracture stresses for five metals are listed in Table 1. The quantity determined experimentally is the differential particle velocity which must be reached at a point in the body before fracturing results. The relationship

$$\sigma = \rho c \Delta v \qquad (3)$$

is then used to compute the critical-normal-fracture stress where Δv is the critical differential particle velocity. Plastic strains are virtually absent and the critical-normal-fracture stress controls failure. This critical-normal-fracture stress is an extremely important mechanical property of a material; perhaps the most important mechanical property when resistance of the material to fracturing under impulsive loads is of primary concern.

Fracturing Due to Relative Lateral Motions. In many cases, the front of the transient disturbance is divergent so that the direction of particle velocity changes from point to point along the wave front. Many fractures that are observed in impulsively loaded bodies can be identified as resulting from this relative lateral divergence of particle velocities. An excellent example of fracturing of the above kind are those fractures which occur within the walls of internally loaded thick-walled cylinders (*11*). Such fractures are illustrated in Figure 5 which is a photograph of a transverse section cut from a 9-in. diam. mild steel cylinder that has been subjected to the action of an explosive charge of the form shown in Figure 1(b). Similar fractures are evident in Figure 9.

Fracturing on Release of Load. Fracturing frequently results from the motions which accompany the volumetric expansion that occurs on sudden release of the load. The material simply cannot expand as rapidly as it is required to do. For example, fractures of this type are commonly found in materials such as mild steel which exhibit a time delay for initation of plastic flow.

In one case (Figure 12) a ¼-in. thick steel plate was sandwiched between two ⅛-in. layers of explosive. The two layers were then detonated simultaneously. The result was that the plate separated into two plates of approximately equal thickness. The plane along which the fracture occurred was exceedingly well defined. In fact, the fracture surfaces were nearly as smooth as a machined finish.

If two small cylindrical charges are placed against a steel plate as shown in Figure 13 and detonated simultaneously, the fracture shown in Figure 14 is generated near the center of the plate. Another example of a fracture that results from release of load is evident in Figure 14. This is the fracture that appears somewhat below the bottom of each of the craters that were made by the charges. The latter fracture occurs only in steel specimens. Brass, aluminum alloy, and copper specimens treated in the same way do not exhibit fractures at these locations. Likewise, the same metals do not exhibit plastic flow properties that depend on time.

A 1-in. diam. solid-steel rod was coated with a ⅛-in. layer of explosive, Figure 1(c). The result of detonation of the explosive is shown in Figure 15. The rod appears to have fragmentized as though it had been blown outward by a high pressure originating along the axis of the rod.

A thin-walled tube was substituted for the solid rod in the foregoing experiment. The result, using a ¼-in. layer of explosive and a 1-in. diam. 1/16 in. wall steel tube, is shown in Figure 16. Apparently, what happens in this case is that the tube collapses under the high pressure of the explosive and forms a small solid rod, which then fragments on release of the pressure. The thicknesses of the fragments are considerably greater than the original wall thickness of the tube, and, indeed, correspond closely to the radius of the solid rod that could be formed from the material in the original tube.

Thick-walled cylinders have been treated in the same manner. Figure 17 is a photograph of a sectioned 2-in. diam., ½-in. wall steel tube after detonation of a ¼-in. thick explosive charge on the outside surface. In this case, the original tube has separated into two tubes. The inner tube has collapsed and then blown apart and, in so doing, has plastered itself against the inside of the outer tube.

Observations on fracturing of metal bodies that have been impulsively loaded through the detonation of explosive charges can be summarized briefly as follows:

Under the high rates of loading involved here metals, to a first approximation, act as brittle elastic solids. Significant plastic flow is usually confined to a region quite close to the area of application of the explosive charge and to regions near free surfaces. A delay in initiation of plastic flow in mild steel probably plays an important part in the elastic behavior of mild steel plates.

In general, the fracture patterns that are generated are complicated although reproducible. It is frequently necessary to bring the specimens under close scrutiny both visually and metallurgically in order to ferret out the details of the geometry of the fracture pattern. The pattern is not a random one but can be, in almost every case, related to predictable transient inhomogeneities of stress. These inhomogeneities result from, and can be related to, interactions between transient pulses. Reflections from surfaces play an important role in determining the specific interactions that will take place. It is in this respect that fracturing under impulsive loading differs so markedly from fracturing under static loads.

Brittle fracturing has been observed in face-centered-cubic as well as body-centered-cubic metals.

The accumulation of information regarding the fracturing of impulsively loaded bodies has proceeded rapidly during the last few years. It is now possible to appreciate many of the phenomena associated with these problems. There does not, as yet, exist a sizeable body of quantitative data: much engineering development must be done before the ideas discussed here can assume practical significance. It is hoped, however, that the concepts may serve as a helpful guide to engineers.

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Presented at A. I. Ch. E. meeting, Chicago, Ill.

NUCLEAR FUTURE

THERE have been outstanding advances in the [nuclear] art. But in the field of generation of electrical power, where nuclear energy conceptually seems to hold its greatest promise, we cannot yet say that we have succeeded for we know that a great deal remains to be done before the cost of nuclear power will be competitive...

There was a time when it was hoped that the problem of making nuclear power competitive in cost could be solved by some revolutionary reactor design. We have experimented with many types of reactors and continue to do so wherever they hold promise.

This policy of development of many types of reactors over a broad field has not been entirely rewarding for we are discovering that the unknown but promising reactor types tend, as they develop, to become quite similar in their economics to the simple reactor types about which we already have considerable knowledge. In other words, as they become better known, they become less promising.

This is not to say that good new types of reactors have not been found, but simply that the new ones have not been revolutionary, have not provided a step toward the objective of cheap nuclear power.

While all of this has been happening, while we have been learning not to count on a new and novel concept for attaining our goal, something else has been happening—less dramatic but with a powerful undercurrent of promise. This something else is simply that the reactor types which we have been working on have been steadily getting better, have been making unspectacular but nevertheless real progress toward the goal of economical power.

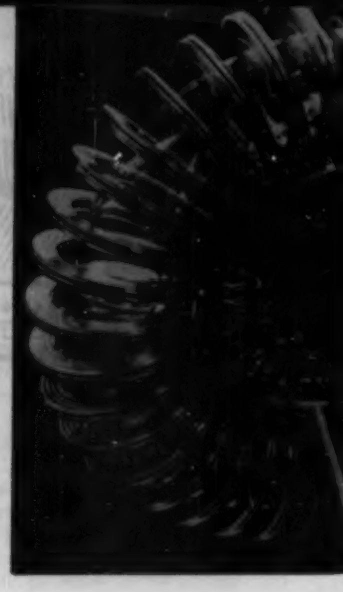
I am strongly of the belief that the development of economical nuclear power is going to follow the same pattern which we see in the steam generating power industry, where in the last twenty years cost of electric power has been reduced 50%, not by any novel change but as the cumulative effect of many individually small improvements, particularly those related to higher operating temperatures . . .

Now I believe that an engineer should never discount the possibility of a major invention, and I believe that the AEC will continue to encourage entirely new reactor ideas and to support them within reason; but, individually, I will place my bet on the steady improvement of existing types of reactors, and it is here that the importance of the development of materials, and fuel cycles, becomes apparent.

HAROLD S. VANCE
Member, Atomic Energy Commission

CEP's 1959 Special Nuclear Report

Courtesy Swiss National Tourist Office



Two interpretations of the 2nd UN GENEVA on the Peaceful Uses of Atomic Energy

1 . . .

S. Lawroski and M. Levenson
Argonne National Laboratory, Lemont, Ill.

The 1958 Geneva Conference was big. More than 6,000 people attended. During the two weeks over 650 papers were orally presented from a total of 2,100 submitted and accepted. Besides this there were two large and interesting exhibits. One of these was a scientific exhibit and the other a commercial exhibit. There were also special lectures, movie programs and supplementary technical literature in the form of pamphlets, reports, and even textbooks. This Conference was about twice the size of the 1955 one and as a result informal sessions and private discussions were very difficult to arrange. With this indicated trend, many people strongly expressed the opinion that the format for future conferences be in the direction of a larger number of smaller and more specialized conferences.

As a result of previous widespread declassification, the scope and detail of subjects discussed were substantially greater at this conference than at the first. This was most notable in the field of fusion research but other areas such as fuel reprocessing and fuel technology were also markedly affected by declassification which had accelerated between the two conferences.

Fusion

The "feature attraction" of the second Atoms for Peace conference was the subject of *Fusion*. Six full sessions were devoted to the subject as compared to no sessions at the first conference. All of the work of the various groups was presented with what appeared to be complete candor, perhaps because practical application seems to be some distance in the future. From a chemical engineering viewpoint, most of the significant facts seem to be negative ones. The large effort being expended on the thermonuclear research is concentrated in the field of plasma physics. Although it appears that chemical engineering problems will need to be solved before power from atomic fusion is a reality, it is too early to even clearly define these problems, let alone work on them. There will probably be purification problems associated with gases, coolants, shielding liquids, and materials of construction. Energy dissipation and heat transfer are other areas where chemical engineers may contribute. At this time, however, the field is largely for plasma-physicists and experts in magnetohydrodynamics and will probably remain so until fusion temperatures have been reached and fusion neutrons actually generated, or perhaps even until a self

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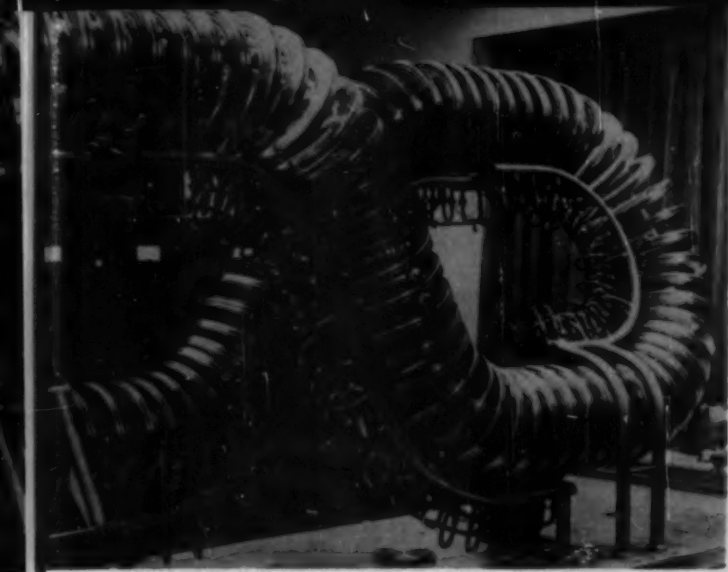

A demonstration model of a "figure-eight" shaped Stellarator, part of the U.S. fusion exhibit at Geneva. The novel shape permits a strong magnetic field to serve as a "magnetic bottle" for the hot, ionized gases in thermonuclear studies.

CONFERENCE

2 . . . W. Kenneth Davis
Bechtel Corporation, San Francisco, Calif.

The general scope of the Second Geneva Conference was much the same as the first, with the significant addition of sessions on controlled thermonuclear work, and some discussion of the peaceful uses of nuclear explosives. In addition to the basic scientific work in physics, mathematics, chemistry, and materials, the discussions covered applications to research and power reactors, propulsion reactors, and the uses of radiation and isotopes in industry, agriculture, medicine, and general research. However, as in the first Conference, the interest centered on the applications for the production of electric power. Fusion reactors had the edge in interest over fission reactors at this conference.

In addition to the program of papers and discussions there were two large exhibits: a major scientific exhibit with many countries participating, and a large commercial exhibit put on by industrial companies from a wide variety of countries. Other features included exhibits of technical literature, a program of movies, evening and special lectures, news conferences, and a variety of informal discussion meetings. When one adds the delegation meetings, lunches, cocktail parties, dinners, and the scenic attractions of Switzerland and France, it is easy to see why no one person would have time to really absorb more than a small portion of what was available at the conference.

The conference was held in the United Nations facilities and was ably organized and run. Sigvard Eklund of Sweden did a magnificent job as Secretary-General of the Conference, upholding the exceptionally high standards set by our own Walt Whitman at the First Conference.

The First Conference was characterized by considerable discussion of the economics of power reactors, and by predictions as to when nuclear power might become competitive with conventional sources of power in various areas of the world.

The discussions at the Second Conference were significant in that there was much less coverage of reactor economics, and in that the discussions were much more realistic and therefore less optimistic with respect to cost and the time scale for the development. This is not to say, as has been reported, that there was any lack of confidence in achieving economically useful power reactors on a reasonable time scale—far from it. However, it was clear that the development work during the intervening three years had had a sobering effect, and that there was now a widespread realization of the difficulties and time involved, and an appreciation that many of the basic economic parameters can be evaluated only by the development projects still under way.

The general consensus was that the first truly economic nuclear-power station would come into operation about 1965, with perhaps a few units, benefitting from special circumstances, be-

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Formerly Director of Reactor Development, U.S. Atomic Energy Commission, Mr. Davis is now Vice-President, Bechtel Corporation.

"... the utilization of fission energy as a source of power is settling down into conventional channels of new product development."

continued

sustaining fusion reaction has been achieved.

Reactors

The large number of papers on fission reactors submitted for the proceedings and presented orally represented an impressive progress report on the development of irradiation facilities and on the application of nuclear energy to the problems of power generation. Essentially all the progress reported, however, was in the construction of plants of the types described at the 1955 conference, in the operation of similar types of plants, or in the investigations of hybrid machines (such as CO_2 cooled—D_2O moderated). No basically new reactor types were disclosed, and all indications are that no such machines have been evolved since the last Geneva conference. Most of the reactor papers have been abstracted and digested, and the entire proceedings will, of course, be available to those interested in details.

From the chemical engineering point of view, the pertinent facts seem to be that the utilization of fission energy as a source of radiation (for test reactors), and as a source of power, is settling down into the conventional channels of new process development. Some of the major question marks of three years ago; e.g., what are likely to be optimum fuel cycles? what is likely to be maximum fuel life?, how advantageous is fuel enrichment?, what reactor type is optimum?, etc.—are all still with us. Many important questions have been answered, e.g., can a boiling reactor be operated without high level contamination of the turbine? What is the coolant decomposition problem in an organic (fluid) moderated reactor? Can reactors be operated at full power day in and day out as base load plants (without spurious scrams)? It is clear that "reactor engineering" and construction can be done by any country that has an advanced industrial technology. Thus the problems of reactor safety are already of world-wide concern. During an informal session on reactor safety (proceedings of the informal sessions are not available) it became clear that those countries that have major reactor installations all face the same systems of control, and to some extent use the same systems of control and check. USA, USSR and UK representatives discussed the use of advisory committees as a safety device and the problems produced for the reactor designer as a result of such committees. While the problems and the treatment of these problems seem almost universal, the solutions arrived at are not. While most reactors built near

". . . underdeveloped countries need many things before they need expensive nuclear power."

continued

ing economically acceptable before that. It was a commonly shared belief that by about 1970 nuclear power would be fully competitive in many areas of the world, and in general use. There was a real appreciation of the problems and the vast amount of work necessary to realize these goals.

At the First Conference there was also a great deal of discussion of the usefulness of small power reactors in underdeveloped countries. The impression was created that nuclear power would be of special usefulness and significance in such areas. There was little discussion of this subject at the 1958 Conference, but again the conclusions from such discussions as were held were much more realistic. It has become clear that the economics of power reactors are greatly influenced by size and by the load factor, and that the most attractive applications, at least at the start, are in industrialized countries which have large electric distribution systems, which can accept large power units because of size and rate of load growth, and which have industrial loads which can provide a high load factor for the nuclear units. Distributions in fuel availability and cost are somewhat secondary to these factors, although competitive conventional fuel costs are an important factor. The cost of nuclear power rises so rapidly with decreases in size and load factor that even high conventional fuel costs still do not justify small nuclear-power stations. It is also true that most of the so-called "underdeveloped" countries need many other things before they need relatively expensive nuclear power.

Controlled thermonuclear reactors

The most significant aspect of the 1958 Conference, at least as seen at this time, was the declassification and discussion of research work on controlled thermonuclear reactors. One surprising aspect is that papers on this subject were presented by scientists from thirteen countries. However, the bulk of the papers, and the most significant ones, were from the U.S.S.R., the U.K., and the U.S.

It was apparent that the U.K. was putting a great deal of effort into essentially one approach, that the U.S.S.R. was putting a great deal of effort into a similar approach and exploring others, and that the U.S. had a broad program covering a variety of approaches including those forming the basis of the U.K. and U.S.S.R. programs. The U.K. program is heavily experimental, the U.S.S.R. program includes some exceptionally good theoretical work, and the U.S. program is fairly evenly balanced between experimental and theoretical work.

Photo Courtesy United Nations

E. I. Dotvokhotov (USSR) reports on controlled thermonuclear reaction studies.

Photo Courtesy United Nations

Courtesy Atomic Industrial Forum

Above, the exterior view of Geneva's Palais des Expositions where the Atoms for Peace commercial and industrial exhibit was held. Right, an overall view of the U.S. section of the commercial exposition.

populated areas in the United States utilize containment vessels, this is not the case in either Russia or England. The British depend on an "inherently safe type of reactor" and the Russians stated that any reactor they built near a populated area was safe; if it wasn't safe, they built it in a remote area. There was little discussion as to how much the cost of containment influenced the various philosophies.

Fuel reprocessing

The field of fuel reprocessing, while of major importance in the utilization of fission energy for power production, was not a major part of the 1958 Geneva Conference. This was largely due to the amount of material previously presented on this subject at the Brussels Conference of 1957 on reprocessing of irradiated nuclear fuels. Any country with a substantial chemical industry can design and build a suitable solvent extraction plant for the reprocessing of spent reactor fuel. Further, all countries with major reactor programs also have significant fuel reprocessing programs. It was quite clear from the papers presented, and from the discussion, that since the primary objective of fuel reprocessing was either the recovery of limited amounts of enriched uranium, or, more generally, the recovery of

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Some concern has been felt about the wisdom of investing huge sums in the development and construction of fission reactors if controlled thermonuclear reactors were likely to displace them in a few years. The declassification and discussions should have laid this worry to rest, at least for the present.

Although a great deal of work was reported on, it was clear that a true controlled thermonuclear reaction arising from the heated plasma has not yet been accomplished for any length of time—whether for micro- or milliseconds. It is also evident that the accomplishment of such an event is only the beginning in the research and development necessary to produce a practical machine that will give a continuous supply of power and an output which is larger than the input. It will be an even longer time before such a device becomes economically competitive with fission reactors or conventionally fueled power plants. Fusion power plants are likely to be expensive and to be extremely large as far as can be foreseen today. They will also have problems of radioactivity and shielding, and so will not differ from fission reactors in this respect.

However, it must be observed that the scientists and engineers working on controlled thermonuclear reactors are generally optimistic about the long-term result. The U.S.S.R. theoretical work casts some doubt on the possibility of utilizing the deuterium-deuterium reaction but the use of deuterium-tritium reactions seems feasible theoretically and practically.

The consensus was expressed by Edward Teller when he indicated that he expected eventual success but did not think controlled thermonuclear reactors should be counted on for power during this century.

U. S. Presentation

The great breadth and depth of the U.S. program for the development of nuclear power was well evidenced by the contributions of U.S. scientists and engineers and by both the scientific and commercial exhibits. Broad and substantial progress was described in the development of basic technology, in the design, construction, and operation of a variety of reactor experiments, and in the design and construction of a substantial number of

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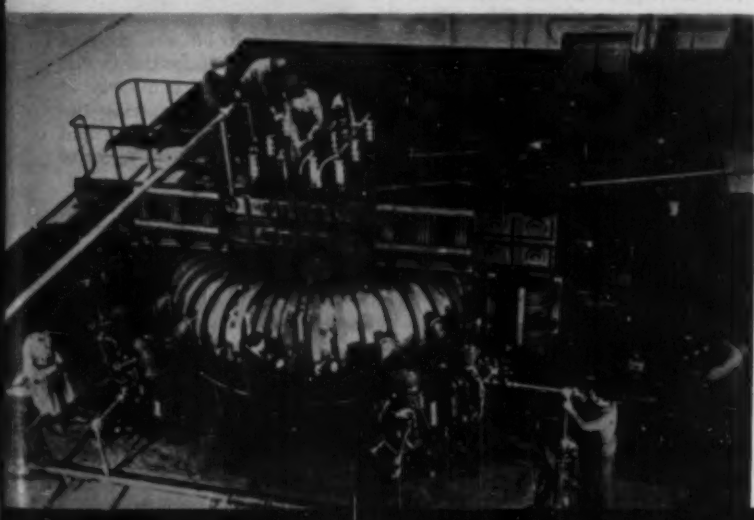

Photo Courtesy Sovfoto

The USSR's thermonuclear installation ALFA, which will be used for physical research work on plasma. The toroidal chamber has large diameter of 4.5 meters.

". . . none of the countries seem to have found solutions to the very serious problems of waste disposal and nuclear safety in fuel processing plants.

continued

weapons-grade plutonium, the use of solvent extraction processes is almost universal. There was little indication that the requirements of nuclear power plants and their fuel cycles is what is directing the route that most fuel reprocessing research is taking.

While most countries seem to be able to find solutions to the problems of plant design and operation, none of the countries seem to have found solutions to the very serious problems of waste disposal and nuclear safety in fuel reprocessing plants. The large volumes of fission product wastes generated by the solvent extraction plants are all presently being stored either as generated, or in a somewhat concentrated form while awaiting a suitable ultimate disposal. Infinite custodial storage rather than environmental dispersion seems to be the likely route, but technical and economic feasibilities have yet to be demonstrated.

The problem of nuclear safety in chemical plants while recognized by all was discussed in detail by few. The informal session on criticality problems of chemical operations was really a detailed description and discussion of the 1958 accident at the Y-12 Oak Ridge plant. The seriousness of this type of problem has been again emphasized by the recent (December, 1958) death at Los Alamos following another such incident. The limited discussion is probably due to the lack of solutions to the problems rather than to classification limitations.

Raw materials

In contrast to the 1955 conference the second Geneva Conference included many papers on the chemical engineering aspects of raw materials. Information with considerable detail and scope was presented by Canada, France, and United States on current refining technology of uranium. These countries also contributed papers on their newest developments in uranium processing for new production plants. The U.S.S.R. papers were few and conspicuously narrow in scope. Within this limitation it was apparent, however, that the Russians have worked along lines which represent some of the improvements introduced some time ago by the United States in its uranium refining operations.

An interesting note on raw materials was the two to four fold larger uranium ore reserves forecast at this conference than in 1955. The revised figures show a likely availability of 2 to 4 million tons of uranium from high grade ore reserves in the free world and the order of 10 million tons of uranium from the total world reserves of similar grade ore. At 30 per cent burnup which might be achieved by use of breeder reactors, the 10 million tons of uranium is equivalent to 3 times the world's estimated coal reserves of 10,000 billion tons. The world's reserves of thorium have been estimated to be at least 500,000 tons.

". . . Despite lack of evidence of real progress . . . the USSR plans for development and construction of experimental power reactors appeared to be well thought out and very sound technically."

continued

large-scale prototype reactors. It seemed that there could be little question about the amount of progress since the First Conference in 1955, which took place shortly after the initiation of the U.S. civilian power-reactor-development program in 1954.

It was only in the area of the application of nuclear power on a commercial basis, the total nuclear kilowatts, that the U.S. appeared to lag behind the U.K. and the U.S.S.R. This results from two factors: one is that it is more difficult for nuclear power to compete with relatively cheap and abundant supplies of conventional fuels in the U.S.; and two, a reason not often appreciated, is that it is easy for the U.K. and U.S.S.R. governments to lay out large, long-range future programs since the power industry is entirely government controlled in these countries. This does not mean that the actual nuclear capacity in the U.S. will be less than in the U.K. or the U.S.S.R. in ten or fifteen years, but only that whether it will be or not depends on success with the development rather than governmental planning.

U.S.S.R. Presentation

The U.S.S.R. presentation at the Conference was something of an enigma and has been reported with varying interpretations. In fact the U.S.S.R. said essentially nothing about its over-all nuclear-power installations program as it had on previous occasions.

The Russian papers on technology were of reasonably good quality but by no means outstanding and did not indicate substantial progress. In this respect they were a considerable disappointment. The U.S.S.R. also admitted that it had not placed any new power reactors, experimental or otherwise, into operation since before the First Conference, and this was a source of considerable surprise to everyone.

Immediately after having conceded that it had no new reactors, the U.S.S.R. tried to make a splash with the announcement (presumably of criticality) of a 100,000 ekw. power reactor but this statement did not have much lasting impact since this was clearly a new plutonium production reactor set up to recover by-product power in a very inefficient manner. The stated steam conditions were 365°F. saturated.

Despite the lack of evidence of real progress, it is still true that the U.S.S.R. *plans* for development and construction of experimental power reactors appeared to be well thought out and very sound technically. The government is following a number of different approaches, is covering the necessary technology adequately, and proceeding through a logical series of experimental reactors in series without seeming to be anxious to build many large power plants prematurely, although such large-scale applications are clearly contemplated as soon as possible in the governmental program. In general, the Russians refused to

Isotopes

Within this broad group the radioisotopes predominated at the conference. It was abundantly clear that application of these materials has become a big and growing business. This growth has occurred primarily in the utilization of the tracer features and ionization sources provided by radioisotopes. Based on reports given at the conference it was estimated that the use of radioisotopes resulted in current annual savings of 400 million and 250 million dollars by United States and Soviet industries, respectively. The principal uses in this country have been in process control, petroleum industry, and other production fields. In papers at this conference, as well as at the previous one, the Soviets reported similar applications of radioisotopes but, in addition, it appears that they have made wider use of these materials in the heavy metallurgical industry than we have.

However, one form of radioisotope application has had considerable difficulty in getting away from the post. It is that of ionizing radiation. In spite of numerous attempts to find economic applications of ionizing radiation in the chemical industry, there has been little success reported thus far. Some promise was indicated in the field of co-polymerization and graft polymerization. Studies of ionizing radiation in the food and pharmaceutical industries have not yet resolved problems of economics and product quality.

Papers at the conference included description of processes as well as plants for the isolation of individual fission products from fuel reprocessing wastes. However, for such uses as ionizing radiation the large scale production of these materials at a really attractive price appeared some time away.

The conference offered some interesting papers on special isotope separations. Perhaps with the hope of stimulating at least some of the Big Three to do likewise, the French presented some excellent papers on their theoretical and experimental work on the separation of U-235 by gaseous diffusion. They also revealed an intent to build a production plant for this purpose. Some time ago the Germans were reported to have developed uranium isotope separation schemes of unusual promise economically. Although they had papers on this subject at the conference, no outstanding claims of promise accompanied the reported results. With regard to other isotope separations, the principal information was that offered by the United States on its experience with the Savannah River Plant for heavy water production.

Economics

The economics of power generation by fission reactors appeared to be the same in 1958 as in 1955 although the forecasts were not the same. During the three years between the two conferences, considerable sobering up has occurred from the 1955 binge of optimistic economics and predictions of time schedules for competitive nuclear power. No one is yet making competitive power but the obstacles are now better recognized. It seems clear that the capital costs of nuclear power stations will not, in the foreseeable future, be substantially cheaper than fossil-fueled plants. A reasonable goal is to reduce the cost of nuclear plants to that of conventional plants. Therefore, any savings must be realized from the cost of the fuel cycle. Most of the papers which discussed

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Photo Courtesy United Nations

Above, members of the Czech delegation relaxing on the Palais grounds during an interval. Left, A.I.Ch.E. past president Walt Whitman, secretary-general of the 1st Geneva Conference, talks with G. Gregoire (far left), and C. J. Mosbacher (far right), UN information officer.

say when the large, end-product power stations were scheduled to be completed.

In its breadth, the types of reactors being developed, and in the general approach, the U.S.S.R. reactor development program is remarkably similar to the U. S. program. Unless the Russians are carefully and consistently holding back technical reports on progress, not by any means an impossibility, it must be concluded that the U. S. has increased its technological lead over the U.S.S.R. in the past three years.

Great interest was evidenced in the U.S.S.R. nuclear-powered icebreaker Lenin which has been launched and which will be powered with three pressurized water reactors. The third reactor is for stand-by use which seems unnecessary to us in view of the great reliability we have experienced with single reactors in submarines. Since the reactors in the Lenin are similar to those used by our Navy, there is, of course, much speculation as to whether or not the U.S.S.R. does not have nuclear-powered submarines despite the lack of any direct evidence that it does.

The Russians were quizzed several times about the 100,000 ekw. power station Blokintsev, at the 1955 Conference, stated would be in operation by 1956, but there was no real explanation for the fact that such a plant has not been put into operation although a similar plant is apparently still planned or under construction.

U. K. Program

The U. K. reactor program has been extensively covered in recent years, particularly the plans to build a large nuclear-generating capacity. However, some fairly important aspects of the U. K. program did crystallize during the Conference.

It was admitted that there were problems with natural uranium fuel elements in gas-cooled reactors and that the U. K. experience did not extend beyond 1300 MWD/T burn-up although they were selling such reactors based on 3000 MWD/T fuel life. It was also brought out that there are safety problems at high burn-up

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continued

economics were optimistic about fuel cycle costs and predicted longer fuel life, lower fabrication and processing costs, and economically feasible solutions to waste disposal problems. However, this same degree of optimism was not reflected in the technical papers on the specific subjects. While reactors are being built by private industry so that actual costs can be determined and evaluated, essentially all fuel cycles are government subsidized, either directly or indirectly, so that at present it is almost impossible to determine the true cost of the fuel cycle of any power reactor. Since these costs cannot be determined, it is very difficult to predict future costs, or to evaluate the expressed optimism.

Technical exhibits

A number of countries participated in the scientific exhibit which was an important part of the conference. Among these the United States exhibit was outstanding. As was the case with the technical sessions, *Fusion* was the "main attraction" at the U.S. technical exhibit. One could not help but be impressed by the array of machines and the ideas they embodied. At the same time one was impressed by the magnitude of the problems still ahead if all the effort and ingenuity that could produce these machines had not produced a single fusion neutron.

The United Kingdom and France also had impressive exhibits. The U.S.S.R. exhibit was much less comprehensive in coverage than the other three previously mentioned but, for some reason, did include a model of Sputnik III.

Apart from the conference, there was a large commercial exhibit displayed in downtown Geneva. Here the United Kingdom exhibit dominated. This, together with exhibits from the other European countries, indicated considerable competition for American industry which also had a substantial exhibit.

continued

due to positive temperature coefficients resulting from high plutonium build-up.

There was also some discussion of Sir Christopher Hinton's earlier statements that the natural uranium, gas-cooled, graphite-moderated reactors are too expensive to build to be considered beyond a certain point in the Electricity Generating Board's programs. The U. K. indicated that it was developing advanced and high-temperature gas-cooled reactors but all of these require the use of enriched uranium, and the high-temperature reactor will necessitate the use of helium available only from the U. S. or by expensive extraction from the atmosphere.

The U. K. is not devoting much attention to other types of reactors except the fast breeder and there was a noticeable lack of optimism about the short-range development and use of fast breeders. The Dounreay fast breeder is now scheduled for operation in 1959. The U. K. is studying the gas-cooled, heavy-water moderated, natural-uranium-fueled reactor but has not arrived at a conclusion on it. The U. K. has made studies of the sodium-cooled, graphite-moderated reactor but has not decided to pursue the development of this type of reactor.

Programs of other countries

Several other countries reported interesting progress in atomic energy. Among these France has made substantial progress which has often gone almost unnoticed. The French atomic energy work is good and is characterized by imagination and boldness.

The French are completing two gas-cooled, graphite-moderated nuclear-power plants which will produce plutonium and some power and they also have a small one already in operation. The big units have prestressed concrete pressure vessels. Electricite de France is well along on building one gas-cooled, graphite-moderated power plant of a considerably different design and is starting a second with still another design. EDF plans to build nuclear-power units staggered about 18 months apart and to build each of them somewhat differently until they find a satisfactory and economical design. It is considering water-cooled reactors in connection with the Euratom program.

The French described considerable work on uranium enrichment by gaseous diffusion and showed some of their equipment—both obviously of high quality. They announced the start of construction of a medium-sized gaseous diffusion plant in the South of France and the intent to build larger ones. Such a program will do much to reassure other countries concerning enriched uranium supplies if they purchase U. S.-type reactors requiring enriched uranium.

Italy has been active with plans to build nuclear-power plants. It proposes to purchase plants from the U. S. and U. K., but to develop its own capabilities as much as possible at the same time. Work started on a U. K. gas-cooled reactor just prior to the Conference, and a second project, that of Senn, was discussed at the Conference although the decision to use a boiling-water reactor was not announced until afterward. A third plant proposed for early construction in Italy is a pressurized-water reactor. There is also great interest in nuclear ship propulsion in Italy.

A tremendous interest is shown in nuclear-power development in West

The 135-ft. sealed sphere of the fast-breeder reactor at Dounreay, Scotland.

Courtesy British Information Service

U.S./EURATOM: *real stimulus to U. S. nuclear power industry*

W. Kenneth Davis

The formation of EURATOM and the proposed joint US/EURATOM nuclear power programs received scant formal discussion at the recent Geneva Conference but were clearly considered of great importance in informal discussions by delegates to the Conference.

While there are many details remaining to be resolved, as well as further Congressional reviews required, it seemed to be the consensus of the U.S. industrial personnel that the joint US/EURATOM program could be a very significant step forward—providing not only needed nuclear power business opportunities but also a proving ground for intermediate-stage U.S. nuclear plants under realistic conditions of use.

The largest impediment, as was the case in the domestic program, was considered to be the question of third party liability. This is complicated by the fact that U.S. developers and manufacturers have more exposure to claims than competitors from many other countries, and also by the fact that in an area such as Europe, indemnification in any one country is not likely to be adequate with other countries so close by.

It is clear that some sort of general solution is necessary for a broad and successful program; and the Organization for European Economic Cooperation has taken steps to try to resolve the problem through an international convention on the limiting of liability.

Construction of some plants (particularly government sponsored plants) will probably proceed before any general solution is reached by individual negotiations between U.S. developers and manufacturers, and the governments involved. This, however, will be a complicated process.

Meanwhile, U.S. manufacturers are actively promoting nuclear plants in Western Europe. Many are setting up jointly-held companies with European manufacturing interests or are licensing them for nuclear components and project participation. The general objective is to make maximum use of European capabilities for manufacturing, design, materials, erection and installation, and to provide the minimum equipment and services from the U.S. This leads to a minimum requirement for scarce dollars as well as to a reduction in nuclear plant costs. However, it does not provide much in the way of business or experience for those U.S. firms supplying conventional equipment and services such as design and construction.

Providing that the program is carried out in a flexible manner, and is not hampered by excessive red tape and extended reviews, it appears capable of providing a real stimulus to the U.S. nuclear power industry, and establishing U.S. reactor technology firmly on an international basis. It may be added that there is little, if any, apparent reluctance to utilize enriched reactors as developed in the United States.

It is important that the US/EURATOM program, while based on providing research and development assistance, loans, and an acceptance of some financial risks, is not set up to be a subsidy program, and thus should lead to truly economic reactors which can be utilized in the very ambitious *future* EURATOM program without costly, continuing U.S. financial assistance.

The United Kingdom, which did much to stimulate the proposed US/EURATOM program by their claims for their reactors, but who have not generally supported the EURATOM concept, are now trying to negotiate for a joint US/EURATOM program. The details of these discussions are not known.

Germany and many programs are getting under way there. These programs are largely in the hands of private industry or the states since there is no atomic energy law in Germany as yet. German interests range from the simplest kinds of power reactors up to very exotic types. It is too early yet to say just what the path will be in Germany, but the country appears capable of making progress now that it is getting facilities and is well started.

The Canadians have been confining their development effort to the heavy-water, moderated and cooled, natural-uranium-fueled reactor because of their resources of natural uranium and their belief that this type of reactor can compete with their relatively cheap sources of conventional fuels and hydroelectric power. Work on an experimental reactor is progressing, but the over-all program is expected to take quite a while.

Japan is continuing negotiations for a large U.K.-type reactor and a small U.S.-type reactor, and definitely foresees large-scale use of nuclear power before long. Norway, Sweden, Netherlands, Switzerland, Belgium, and a few other countries are continuing their own power reactor development work on a smaller scale, and are also anticipating purchase of reactors or components in other countries. Spain, Portugal, and some of the South American countries expressed interest in the use of power reactors.

Conclusion

This review has necessarily been quite general and has emphasized power reactors despite the many other important subjects discussed. In fact, one obvious conclusion is that a Conference as big and as complex as the 1958 Geneva Conference is just too large to be really effective. However, it must be concluded that it was effective in providing much material for later study, and some data from the U.S.S.R. which would probably not otherwise have been obtained.

Due to the widespread declassification there was virtually nothing really new disclosed at the Conference, and even in the area of controlled thermonuclear processes the disclosures while interesting were hardly sensational.

It does not appear that there can be any question but that the U.S. leads the world in its development programs in both fission and fusion power and in the broad application of nuclear energy to a wide variety of uses.

Despite the sobering effect of three years of hard work there does not really appear to be any doubt but that nuclear power will be successfully developed for economic use in the foreseeable future. The next conference, if one is indeed held about 1961, should see this goal near accomplishment.

Presented at A.I.Ch.E. meeting, Cincinnati, Ohio.

W. A. Rodger
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Chemical Engineering GUIDE to Technology at Geneva 2nd Nuclear Conference

The 1958 Geneva Conference was characterized by the submission of a large number of good reviews of wide segments of the field and by the submission of papers from a number of smaller foreign countries describing work which in general confirmed that which had been done previously in this country, Canada, and the United Kingdom. In the following, no attempt will be made to mention each of the 200-odd papers reviewed, but the highlights of a number of specific subjects will be mentioned. A total of 67 foreign and 128 U.S. papers on various chemical engineering aspects of nuclear energy have been reviewed.†

It is by now clear that little new material was presented at the 1958 Geneva Conference. This was due in part to the fact that, unlike 1955, there was not a large body of newly declassified material available and, in the field of separations processing in particular, to the fact that in May, 1957, there was held in Brussels a Symposium on Chemical Reprocessing which brought much of the subject up to date at that time.

Feed materials

Numerous U.S. papers were given on the processing of uranium ores and the various steps in the conversion of intermediates therefrom to desired end products. In paper 512* pilot plant studies of alkaline backleaching of uranium ores were described. During the period 1953 to 1957 all the new uranium mills built in the United States incorporated acid-leach processes due to the advancements made in the fields of ion exchange and solvent extraction for selectively recovering uranium values from acid-leach liquors. New knowledge and process improvement in carbonate leaching have resulted in the construction of four new mills which use alkaline-leach methods for uranium recovery. It was expected that by the end of 1958 alkaline mills would be processing approximately 5000 tons ore/day or roughly 25% of the concentrate production of the United States.

It seems likely that the cost of uranium purification could be reduced if purified product were produced directly at the ore-treatment plant. Two papers (496 and 498) discussed possible processes, the more promising method being one in which the ore would be contacted directly with a solution of alkyl phosphoric acid in an organic diluent.

† *It has been surprisingly difficult to obtain copies of some of the papers so that an additional 35 papers were not available for review and are listed only by their titles.*

* *Papers marked thus were presented orally.*

The current US manufacturing processes for the large-scale production of UF_6 from purified UO_3 were outlined in paper 1840*. The techniques involved are fluid-bed reduction of UO_3, ribbon-screw hydrofluorination, flame-reactor conversion of UF_4 to UF_6, and product UF_6 condensation. Chemical efficiencies of 99% and uranium yields above 99.99% were reported. The UF_6 product has a purity of 99.99%.

The newest US plant for the production of UF_4 and uranium metal at Welden Springs, Missouri, is described in paper 602*. Pilot plant development work has been done on moving-bed reactors for the production of uranium tetrafluoride (1015) and on a fluid-bed process for the production of refined UF_6 from ore concentrates (1552*).

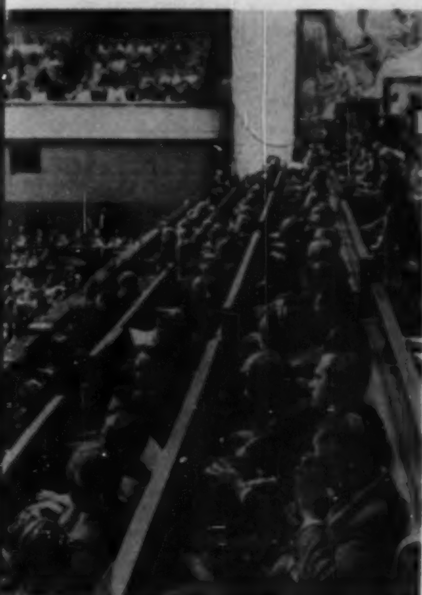
Fluorine is used in large quantities in preparing UF_6 as feed to gaseous diffusion plants. The design of a plant with a capacity of 7600 lb. fluorine/day was given in paper 524. Capital costs for the plant were estimated at four million dollars and, with a 20-year amortization of the facility, a cost of a little over 50¢/lb. fluorine was predicted.

Papers on feed material were also written by the United Kingdom, Canada, USSR, Japan, Spain, India, Israel, Yugoslavia, France and the Federal Republic of Germany. A

Russian paper, 2063*, discussed the possibility of extracting uranium from natural waters containing low concentrations of the element (0.06 mg/liter). Coprecipitation, sorption, and extraction processes were considered. It appears that the work was done in 1952 and 1953.

France disclosed the location, purpose, and raw materials of her various ore-processing plants (1254*). Acid-leach ore processing is used, followed by direct precipitation of a uranate, or a uranous phosphate, and by ion exchange.

Israel (1609) recovers uranium in the Negev as a by-product from the



Opening meeting in the Assembly Hall of the Palais des Nations.

production of dicalcium phosphate. Process descriptions and flowsheet were given. Studies on the processing of their domestic ores were also reported by Japan (1361) and Yugoslavia (485).

The methods used by their respective countries for preparing pure uranium tetrafluoride from ore concentrates were reported by Canada (229*), France (1252*), and India (1668). The Canadians pelletize UO_3 and reduce it in a 20-cm.-diam. shaft furnace. The UO_2 which remains in the form of pellets is charged to a similar reactor for hydrofluorination with anhydrous HF. The French reported a production of 300 tons uranium in 1957 at Le Bouchet. In India the ore concentrate is obtained as a by-product of the thorium industry.

Two processes used in the United Kingdom for thorium extraction (1468*, 1526) are based upon the sulfuric acid breakdown of monazite, followed respectively by selective precipitation of thorium oxalate or by adsorption upon cellulose phosphate. A third process involves the pretreatment of monazite with dilute acid to render it more amenable to subsequent alkali breakdown. Two new sources of thorium are available: Nigerian thorite ore, consisting mainly of thorium and zirconium silicates, and the barren liquors from several of the Canadian extraction plants. In all cases where reactor grade thorium is required an additional purification stage is necessary. This is generally based on solvent extraction with tributyl phosphate (TBP). A process for making thorium metal is based on the chlorination of thorium oxides suspended in a sodium chloride-potassium chloride melt, using chlorine in the presence of a reducing agent.

The French are extracting thorium from Madagascar ore at the Le Bouchet plant (1251*) and in India domestic monazites are quite available (1670*).

Processing

Solvent Extraction. Not unexpectedly, numerous papers were prepared on the subject of solvent extraction. The basic US review paper (2409*) discussed improvements in the solvent-extraction process including the recycle of wastes, the use of temperature differentials to improve fission product decontamination in Purex processing, alternate concentration processes for both plutonium and uranium product streams, and solvent-extraction processes for thorium and for highly enriched uranium. There is a section on chemical and radiation damage of solvents and on the use of potential new solvents such as organophosphorus compounds.

Direct maintenance operating experience has been obtained in the Metal Recovery plant (four years), the Thorex Plant (seven years) at Oak Ridge (536*), the Purex hot solvent-extraction pilot plant (516) at Hanford, and the Idaho Chemical Processing Plant on zirconium alloy fuels (526*). At the last-named plant, complete decontamination and recoveries of 99.7% of the enriched uranium were achieved. Recovery costs for this fuel are high because of the small quantity of material processed.

The effect of temperature on the Purex process was investigated in miniature mixer-settler units (519). Operation of a two-cycle uranium-235 process at 70°C. gave consistent decontamination factors of 2×10^8 compared to 3×10^6 at 30°C. At 30°C. the principal fission-product contaminant in first-cycle product streams is ruthenium, whereas at 70°C. it is zirconium-niobium. This suggests the possibility of using a dual scrub section, one operated at low temperature to remove zirconium-niobium, and the other at high temperature to remove ruthenium. In laboratory studies one solvent extraction cycle with dual temperature scrub section combined with adsorption or ion exchange processes for both product streams achieved decontamination factors equal to or greater than the two-cycle Purex process.

A Russian paper (2182*) described the processing of fuel elements from the first atomic power station in the USSR. The fuel element is 88 wt. % uranium-molybdenum (9% Mo) and 12 wt. % Mg. It is clad in stainless steel. Stainless steel is removed mechanically. The declad fuel element is dissolved in nitric acid containing ferric nitrate (6 g./liter) or phosphoric acid (20 to 40 g./liter). The feed solution is 5 *M* nitric acid and contains 70 to 120 g./liter uranium. Recovery and decontamination are effected by solvent extraction using a 20% solution of TBP in kerosene.

The British have operated a chemical plant located at Windscale for six years (307*). It is a liquid-liquid extraction plant which employs β dibutoxy diethyl ether (Butex) for the primary separation and for uranium purification, and TBP in kerosene for plutonium purification. The British have built plants for processing enriched uranium at Dounreay (82*).

The French solvent-extraction pilot plant at Fontenay-aux-Roses (1172*) and the design and construction of the Marcoule plant (1174) were covered as was the design of the Norwegian-Dutch (JENER) solvent-extraction pilot plant (585*) which will have a capacity of about 3 tons/yr. Sweden has worked on a method of using a silica gel column to replace the uranium-plutonium partition column in a Purex flowsheet (144*). None of these descriptions, foreign or domestic, presented anything very new.

Non-Aqueous Separations Process. Nearly all of the papers written on the subject of nonaqueous separations processing were from the United States. Two review papers (539 and 2388*), were given on the various

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continued

fluoride volatility processes being studied in the United States. Processes employing bromine trifluoride and chlorine trifluoride for the dissolution of natural uranium were discussed, as were fused salt processes for aluminum, zirconium, and stainless steel fuels. Recent work on the chemistry of plutonium hexafluoride which may permit the extension of volatility processing to fuels containing significant quantities of plutonium was also included. Aircraft Reactor Experiment fuel has been processed in a volatility pilot plant (535). The fuel consisted of a fused salt 22.8 wt. % NaF, 69.5 wt. % ZrF_4, and 7.7 wt. % UF_4 which melts at 525°C. The uranium was about 90% enriched. Essentially complete decontamination of the low level of activity in the fuel was realized and 97% recovery of product was obtained with only 0.01% being found in the waste salt. The Russians also presented a paper on the chemistry of plutonium fluorides (2208).

Recent developments in pyrometallurgical processing, particularly the work directed toward the development of the pilot plant for the Experimental Breeder Reactor-II (EBR-II), were reviewed in papers 1795*, 541, 538, and 529. The recent development work on melt refining and other pyrometallurgical processes has been encouraging and the design of the fuel-recycle facility, which is a circular shielded cell containing an inert atmosphere, is well along. Work on pyrometallurgical processes other than melt refining, particularly those which are based on fractional crystallization from liquid-metal solvents, was reviewed in papers 540 and 517.

The British (32*) are working on the melting of uranium in contact with liquid calcium in tantalum crucibles. Distribution coefficients for plutonium, uranium, rare earths, and some fission products were given over a range of concentrations and temperatures.

Considerable interest in fluidization has developed in the atomic energy field within the last few years, and a number of applications are under investigation. Recent developments have opened the way toward applying fluidized-solids techniques to the processing of nuclear fuel materials such as uranium and plutonium both irradiated and nonirradiated (542).

Ion Exchange. Two US papers (520 and 1915) described the application of ion exchange to the isolation and purification of uranium, plutonium, and neptunium. The latter paper considered the use of anion exchange resins for the processing of plutonium. Anion exchange offers a marked advantage over cation exchange for plutonium processing. The decontamination factors are greater than 5×10^3 for fission products and 5×10^4 for uranium and other metallic impurities. Product concentrations above 50 g. Pu/liter are readily obtainable in a single anion exchange cycle. A Dutch paper (1476*) discussed mechanisms of radiation damage in ion exchange resins. Most organic ion exchangers are found to be stable up to 10^8 to 10^9 rad. Inorganic ion exchangers are stable to over 10^9 rad.

Isotope Separation. A surprising number of papers were presented on isotope separation. Most of the US papers on this subject were on production of heavy water. France had a considerable amount to say on the separation of uranium isotopes. One of the US papers (1063) described the design of a heavy-water plant to operate on hydrogen from an ammonia synthesis plant. Another (1065*) discussed the final concentration of heavy water by distillation and electrolysis. Operating experience on two of the three steps used at Savannah River were given, that is vacuum distillation and electrolysis. India (1649*) described a plant under construction in the Punjab to produce 14 tons of heavy water/yr. along with 70,000 tons of nitrogen as nitro-limestone. It is expected that the heavy water will cost no more than $28/lb. Israel (1611) described the design of the final enrichment distillation section for taking heavy water from 15% to 98.8% D_2O. This plant has a capacity of 50 tons/yr.

In a paper from the Federal Republic of Germany (1002*) the separation of uranium isotopes by pressure diffusion in a free-expanding jet stream is outlined. Experimental work has been done with argon isotopes. The French (1262*) reported the principal results obtained in studies on the separation of uranium isotopes by gaseous diffusion. They described barriers made by treating a foil of solid solution of gold-silver (40-60) with 36° Baumé nitric acid, producing a barrier with pore radii of about 300 A° and a permeability of about 8×10^{-5} moles (sq. cm.) (min.)/(cm. of Hg pressure difference). Another barrier with excellent characteristics was obtained by the anode oxidation of aluminum foil in a bath containing sulfuric or oxalic acid. The French have also studied barriers obtained by fritting finely powdered alumina at about 1150°C., and barriers of Teflon obtained by rolling an emulsion precipitated on a metal mass. The Russians (2086*) described an experimental and theoretical investigation of separation of isotopes by diffusion in a current of auxiliary vapor. The paper gives results obtained in 1956 and 1957.

Economics

Fuel Cycle. There is now considerable interest in the consideration of the complete fuel cycle, particularly as regards minimizing costs; that is, not only must the cost of building and operating a reactor be taken into account, but also the removal of a spent fuel element from the reactor, its processing, and return to the reactor must be considered. All the pertinent papers obtained for review on this subject came from the US.

Three papers (442, 755, 1838) considered the build-up of isotopic contaminants during successive irradiations and recycle of nuclear fuel. For U-238 fuels there are two alternatives, either complete decontamination, which includes long decay times to permit contact refabrication of fuel elements, or partial decontamination with remote refabrication. The major problem associated with radiation in natural or slightly enriched uranium fuels is due to U-237. It is estimated that removal of 25% U-236 content in a gaseous diffusion plant can reduce the necessary decay time for U-237 by 30 days. On the other hand, the build-up of activities in plutonium, U-233, or thorium systems follows definite patterns and these activities cannot be reduced to allowable levels unless excessive decay periods are used. For these fuels remote, or at least semiremote, refabrication facilities will be required.

Three papers (1016, 1044, 1068) analyzed theoretically the fuel cost of

Table 1. Ground disposal of liquid waste at three major production sites[a]

	Cumulative total volume (liters)	Cumulative total gross Beta-emitter activity (curies)
SAVANNAH RIVER	5.0×10^8	2.4×10^2 [b]
OAK RIDGE	2.6×10^7	1.0×10^5
HANFORD	1.2×10^{10}	2.4×10^6

[a] Paper 1767

[b] Not including 2300 curies of I^{-131}

various reactor fuel cycles. Based on available estimates for present and long-range fuel-cycle costs, the following conclusions may be drawn:

1. Below a reactor feed concentration of roughly 1.5% U-235, major savings may be effected in the burn-up cost/g. U-235 consumed by keeping the enrichment as low as possible. Above 1.5% U-235, the burn-up cost is almost independent of enrichment.
2. For the Th-U-233 cycle and for most slightly enriched uranium-plutonium cycles, major short term emphasis must be placed on achieving long exposure levels.
3. If the plutonium credit is $12/g., recycle of plutonium in reactors such as the Calder Hall type appears economic.
4. In the long range, the relatively high conversion ratios of the Th-U-233 cycle makes this cycle look particularly attractive in heterogeneous thermal reactors.

Criticality. Two US papers discussed the subject of criticality (427 and 518). The former described the production precautions taken in the unirradiated processing phases of enriched uranium fuel cycles while the latter described some critically safe equipment for aqueous separation processing. In particular a slab-type mixer settler and a continuous solvent washer were described in some detail.

Radiation Utilization. In the reasonably near future Co-60 radiation could be available at $2.50/kw.-hr. including return on investment, electron beam energy at $1.00/kw-hr., and reactor irradiation at $0.15 to $0.35/kw.-hr. (795). Still, no one has found a really outstanding use for utilization of radiation in chemical processing. Two papers (794 and 797) considered the effect of gamma radiation on low-temperature oxidation of propane and the self-oxidation of hydrocarbons. Some foreign irradiation facilities were described. A French facility, (1212*) built in conjunction with the high-flux Saclay Reactor EL-3, provides radiation intensities from 1 to 5 $\times$ 10^5 r/hr. A Russian facility (2085*) using 16,000 gram equivalents of radium as Co-60, gives an average calculated dose rate of 570 r/sec. It is being used to study the effect of radiation upon the vulcanization of rubber.

Waste Disposal

The subject of waste disposal, a popular one, produced numerous papers from the United States and foreign countries. The United States has had considerable experience in the storage of high-level radioactive wastes over a number of years (389*). Tank storage is admitted to be an interim method but the present state of knowledge is such that the technique has the advantage that the wastes are under control, their location is known, and the operating experience to date has been satisfactory.

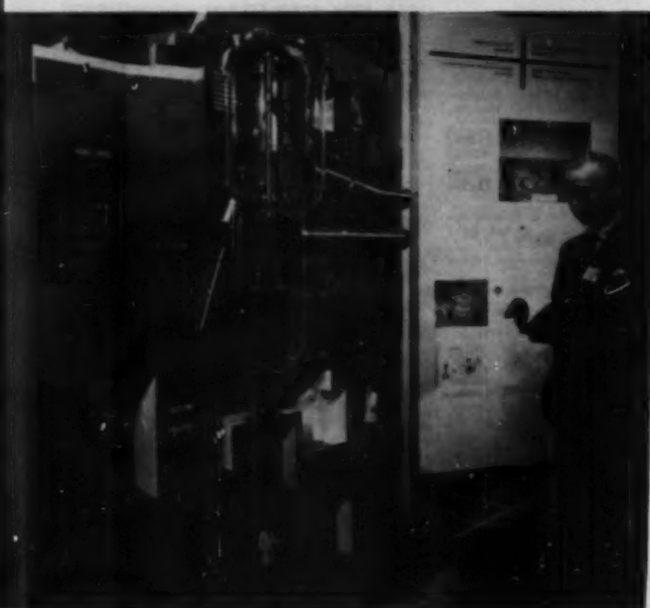
As an adjunct to storage in tanks most operating sites now discharge at least some lower level wastes directly

continued

At the Scientific Exhibit

One of the main features at the Conference was the Scientific Exhibit in a building specially erected on the Palais grounds. Left, some of the many visitors enter the exhibit building. The U. S. exhibit, one of the largest, devoted a great deal of space to various aspects of thermonuclear research in this country.

Advances made in liquid metal technology were presented by Atomics International Division of North American Aviation. A liquid metal loop is shown here to display the operations of various devices involved.



An animated cutaway model of the Engineering Test Reactor in Idaho, together with illustrated panels, was one of the features of the American exhibit.

Windscale plutonium producing factory at Sellafield, Cumberland, England. The filters at the top of each of the 400 foot high chimneys prevent the escape of the last traces of radioactive matter.

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to ground (2351 and 1767*). Twelve years of practical experience in the controlled disposal of waste to the ground at Hanford, seven at Oak Ridge, and four at Savannah River have demonstrated the feasibility, safety, and economy in such disposal of some types of liquid wastes at shallow depths. The ground disposal experience at these three sites is summarized in Table 1.

Disposal of waste to the oceans has international aspects (2431) and there are numerous areas of research which must be exhaustively followed before the ocean can be considered as a safe place for disposal of radioactive wastes on a large scale. Both the British (296 and 297*) and the Russians (2058*) gave papers on the disposal of radioactive wastes into the sea. In paper 297* the British gave extensive data on their experience of five years in putting radioactivity into the Irish Sea from the Windscale plant where they have been discharging radioactivity at the rate of about 3000 curies/month. They have concluded that it would be safe to release as much as 20,000 curies/month at that point. The limiting factor is activity adsorbed in a seaweed which grows along the Irish Sea coast and is harvested and made into a bread which is eaten by the Welsh. They also describe (296) a survey carried out on the south coast of England near Winfrith Heath preparatory to establishing a new atomic energy site at that point. Dyes were used in these experiments which were similar to "Operation Seanuts" carried out some years ago at Sellafield preparatory to the disposal of waste at Windscale. They have concluded that it will be possible to regularly discharge 25,000 curies a month two miles out to sea on the south coast of England. In all probability the initial discharge will be in the order of 1/10 of this amount.

The Russian paper (2058*) considers the disposal of large quantities of radioactive waste into the deep sea trenches. Their conclusion is that the

GENEVA PAPERS REVIEWED—a bibliography

32 Processing reactor fuels by liquid metals, F. S. Martin, et al.

82 Chemical processes at U.K.A.E.A. Works, Dounreay, C. Buck, et al.

144 Sepn. Pu from U by partition between organic solvent and stationary water phase on silica gel, A. Hultgren, E. Haeffner.

195 Disposal fission products in glass, L. C. Watson, et al.

229 Canadian Dev. Work, Moving-bed Reactor Redn. UO_3, Hydrofluorination to UF_4, P. W. Melvanin.

296 Sea disposal of low activity effluent, P. Bowles, et al.

297 Disposal Radio. Liquid Wastes into Coastal Waters, H. J. Dunster.

307 Chemical proc. Irrad. thermal reactor fuels, G. R. Howells, et al.

309 Recov. of Kr from dissolver waste gases by fract. solvent extraction, R. W. McIlroy, et al.

388 Retention of fission prods. in ceramic glazes, M. I. Goldman, et al.

389 Storage high level wastes, des. and operg. exper. in U.S., O. H. Pilkey, et al.

395 Removal of Sr from wastes by calcite-phosphate mechanism, L. L. Ames, Jr., et al.

397 Treatment of radio. waste gases, A. G. Blasewitz and W. C. Schmidt.

427 Nuclear safety in unirrad. proc. of enriched-U fuel cycles, J. D. McLendon, et al.

442 U-236 Problem in combined operation of power reactors & isotope sepn. plants, G. A. Garrett and S. A. Levin.

485 Redn. of U from carbonate solns. with H_2 & UO_2 catalyst, B. Bunji and B. Zogovic.

496 Recov. of U from ores by organic solvent leaching, J. E. Magner and R. H. Bailes.

498 Improved Methods for Preparation of High-purity Uranium Salts, R. S. Long, et al.

512 Pilot Plant Alkaline Leaching of Uranium Ores, R. G. Beverly and W. D. Charles.

516 Op. Experience in a Hot Solvent Extraction Pilot Plant, G. C. Ohlberg and R. J. Sloat.

517 Pyrometallurgical Processing, P. Chiotti and A. F. Voigt.

518 Critically Safe Equipment for Aqueous Separations Processes, T. J. Colven.

519 Temperature Effects on TBP Solvent Extraction Processes, D. G. Karraker.

520 Conc. and Purif. of U, Pu, and Np by Ion Exchange in Nucl. Safe Equipment, F. W. Tober.

524 Multiton Production of Fluorine for Manufacture of UF_6, A. P. Huber, et al.

526 Zirconium Alloy Fuel Reprocessing, D. G. Reid, et al.

529 Pyrometallurgical Purif. of Pu Reactor Fuels, J. A. Leary, et al.

535 Recov. of U. from Highly Irradiated Reactor Fuel by a Fused Salt-Fluoride Volatility Process, G. I. Cathers, et al.

536 Oper. Experience with Two Direct-maintenance Radiochemical Pilot Plants, P. R. Bruce, et al.

538 Developments in Melt Refining of Reactor Fuels, L. Burris, et al.

539 Recent Developments in Fluoride Volatility Processing of Reactor Fuels, R. K. Steunenberg, et al.

540 Purif. of Reactor Fuels and Blankets by Crystallization from Liquid Metal Solvents, H. M. Feder and R. J. Teitel.

541 The Pyrometallurgical Process and Plant for EBR-II, M. Levenson, et al.

542 Fluidization Techniques as Applied to Reactor Fuel Processing, S. Lawroski, et al.

585 The Joint Establishment for Nucl. Energy Research Reprocessing Pilot Plant, T. J. Barendregt and L. K. Lund.

602 The Newest U.S. Uranium Processing Plant, H. E. Payer.

755 Surface Dose from Plutonium, W. C. Roesch.

794 The Effect of Gamma Irradiation on the Low-Temp. Oxid. of Propane, J. L. Liebenthal, et al.

795 The Use of Nuclear Radiation in Chem. Proc. Operations, F. T. Barr, et al.

797 Radiation Initiated Sulfoxidation of Hydrocarbons, J. F. Black and E. F. Baxter, Jr.

1002 Separation of the Uranium Isotopes by the Nozzle Process, E. W. Becker, et al.

1015 A Moving-Bed Reactor for the Production of UF_4, D. S. Arnold, et al.

1016 Fuel Cycles in Single-region Thermal Power Reactors, T. H. Pigford, et al.

1044 Fuel Cycles for Nuclear Power Reactors, D. P. Herron, et al.

1063 Some Aspects of Heavy-water Production by Distillation of Hydrogen, B. M. Bailey.

1065 Concentration of Heavy Water by Distillation and Electrolysis, W. P. Bebbington and V. R. Thayer.

1068 The Comparative Econ. of Pu Fuel Utiliz. and U-235 Fuel Utiliz. in Thermal Power Reactors, E. A. Eschbach, D. P. Granquist, and M. Lewis.

1172 The Processing of Irrad. Uranium, Results of the Operation of the Fontenay-aux-Roses Pilot Plant, P. Regnaut, et al.

1174 Problems Raised by the Constr. of the Pu Extraction Plant: Some Solutions at Marcoule, M. Curillon and M. Coeure.

1178 The Indust. Probs. Raised by the Proc. of Radioactive Liquids: Some Spec. Solutions Applied at Marcoule, C. Bernaud.

1179 A Pilot Unit for the Separation of Cs-137, A. Ruggenbass, et al.

1212 The Construction of a Semi Industrial-Type Gamma Irrad. Facility, P. Balestic, et al.

1251 The Manufacture of Pure Thorium Nitrate at the Le Bouchet Plant, C. Braun, et al.

1252 Improvs. Made in Methods of Purifying U Compounds and in the Prod. of U Metal at Le Bouchet Plant, J. Decrop, et al.

1254 The Chem. Treatment of U Ores in France, P. Mouret and R. Sartorius.

1262 Principal Results Obt. in France in Studies of the Sepn. of the U Isotopes by Gaseous Diffusion, C. Frejacques, et al.

1361 On a Process for Recovering Uranium from Japanese Ore, Shiro Yamagata and Yoshiki Imai.

1468 Thorium Metal Production by a Chlorination Process, A. R. Gibson, et al.

1476 The Irradiation of Ion Exchangers in JEEP, K. A. Nater.

1526 Recently Developed Processes for the Extr. and Purif. of Thorium, A. Audsley, et al.

water in the deep trenches is rather rapidly mixed with surface water and that it would not be a suitable place for the discharge of large quantities of radioactive waste.

Gaseous wastes at Hanford (397*) are treated by the use of fixed bed, glass-fiber filters. Silver reactors are used to remove iodine from process gases and operating data for these were given in some detail.

Fission products maye be retained in ceramic glaze fusions (388). It was concluded that the most desirable product would contain a maximum alumina content and as low a flux and lime content as fusion requirements will allow. Glazes have been irradiated to levels up to 10^8 r with no indication of detrimental effects on leachability.

Liquid wastes may be converted to solids by a fluid-bed calcining process (1922*). The operation of a pilot plant which has determined the behavior of fission products during calcining and the design of a four million dollar plant to be installed at Idaho were described.

The recovery of specific fission products from waste streams was considered in papers 395, 1179* and 1768*. It was refreshing that the relation of fission-product recovery to waste disposal was more realistically appraised in these papers. For instance, in paper 1768* it was indicated that currently available large-scale wastes contain cesium-137 and strontium-90 in concentrations of between 10^3 and 10^4 $\mu c/ml$. To reduce these nuclides to drinking water tolerances, minimum decontamination factors of 10^8 and 10^9, respectively would be required. Suggested recovery processes give decontamination factors ranging only from about 10 to 100. Economically competitive processes giving decontamination factors of 10^3 may possibly be devised but it appears highly improbable that competitive processes giving decontamination factors of 10^8 to 10^9 can be developed.

Among the numerous foreign papers on waste disposal the French described the processing of radioactive wastes at their Marcoule plant (1178*). The process used is one consisting of coprecipitation and chemical coagulation. Reagents used are monosodium phosphate, tannin, and sodium sulfate plus an organic coagulation additive. Decontamination factors expected range from 10 to 100. Two Russian papers (2024* and 2025*) outline the treatment of laboratory wastes. In one case the process used is ion exchange and in the other a precipitation and coagulation process using ferric sulfate and caustic soda.

The British are recovering radiokrypton from dissolver waste gases (309*) by absorbing the krypton in CCl_4 in an absorption tower. Recoveries of better than 99% with volume reductions by a factor of 70 have been obtained in two separate 6-ft. columns.

The Canadians (195*) gave additional data on their nepheline syenite process for incorporation of wastes into glasses. A complete process description was given and a cost estimate indicated that it should be possible to operate the plant for no more than 0.05 mill/kw.-hr.

1552 **Prodn. of Refined UF_6 from Ore Concent. by Fluidizn. and Fract. Dist. Techniques**, S. Lawroski, et al.

1609 **The Electrodeposition of Uranium from Monocalcium Phosphate Solution**, E. Foa, et al.

1611 **Design of the Final Stages of Deuterium Producing Plants**, Y. Lehrer and Y. Weissman.

1649 **Production of Heavy Water in India**, D. C. Gami, et al.

1668 **Studies on the Prepn. of Pure UF_4 from Crude Sodium Diuranate**, V. V. Dapade and N. S. Krishna Prasad.

1670 **Production of Nuclear Grade Thorium Nitrate**, S. Fareeduddin, et al.

1767 **Experience in the Disposal of Radioactive Wastes to the Ground**, R. E. Brown, et al.

1768 **Fission Product Recovery from Radioactive Effluents**, R. L. Moore and R. E. Burns.

1795 **Developments in Pyrometallurgical Processing**, by J. H. Schraidt and M. Levenson.

1838 **Radiation Limitations on Recycle of Power Reactor Fuels**, E. D. Arnold.

1840 **Current Manuf. Processes Used in the U.S. for Mass Production of UF_6 from Purified UO_3**, C. A. Powell.

1915 **Application of Anion Exchange to the Reprocessing of Pu**, J. L. Ryan and E. J. Wheelwright.

1922 **Fluidized-bed Conversion of Fuel Processing Wastes to Solids for Disposal**, J. W. Loeding, et al.

2024 **Decontam. of Low Saline and Low Active Effluents of Radiochemical Industries**, S. A. Voznesensky, et al.

2025 **Pilot Plant for Decontamination of Laboratory Liquid Wastes**, K. A. Bolshakov, et al.

2058 **Concerning the Possibility of Disposing of Radioactive Waste in Ocean Trenches**, V. G. Bogorov and E. M. Kreps.

2063 **Extraction of Uranium from Natural Water**, B. N. Laskorin, et al.

2085 **The Effect of Ionizing Radiation on Elastomers and Vulcanized Rubbers**, A. S. Kuzminsky, et al.

2086 **Isotope Separation by Diffusion in a Stream Current**, L. G. Gverdtsiteli, et al.

2182 **Some Peculiarities in Treating Irrad. Fuel Elements at the First Atomic Power Station in the USSR**, V. B. Shevchenko, et al.

2208 **Preparation and Properties of Plutonium Fluorides**, V. Fomin.

2351 **Disposal of High Level Radioactive Liquid Wastes in Terrestrial Pits—A Sequel**, W. de Laguna, et al.

2388 **Fluoride Volatility Processes for Spent Reactor Fuels**, R. K. Steunenberg and R. C. Vogel.

2409 **Aqueous Processes for Sep. and Decontam. of Irrad. Fuels**, V. R. Cooper and M. T. Walling, Jr.

2431 **Oceanic Research Needed for Safe Disposal of Radioactive Wastes At Sea**, by R. Revelle and M. B. Schaefer.

Other Geneva papers of interest not available for review at the time of preparation of this article.

104 **The Role of the Diluent in the Extrn. of U. by Butyl Phosphate**, R. Bevy, Belgium.

326 **Fixation of Br and of UF_6 on Carbon**, J. Maire, France.

396 **Incineration of Radioactive Wastes**, G. Morgan, U.S.

400 **Some Recent Developments in Reclamation and Waste Disposal**, L. Gemmell, U.S.

464 **Fast Reactor Fuel Cycle Economics**, W. H. Jens, et al., U.S.

507 **The Selection of U from Aq. Solutions by Liquid-Liquid Extraction**, E. H. Crabtree, et al., U.S.

527 **Technical and Cost Aspects of Spent Fuel Reprocessing**, D. G. Reid, et al. U.S.

1033 **Management of Nuclear Materials in a Large Gaseous Diffusion Plant**, W. D. McCluen, et al., U.S.

1046 **The Physical Metallurgy of Pu and Its Alloys**, A. S. Coffinberry, et al., U.S.

1171 **Final Purif. and Conc. of Pu after Treatment of Irrad. U Fuel at the Pilot-Plant of Fontenay-Aux-Roses**, I. Prevot, et al., France.

1173 **Study of Pulsed Columns with System: Uranyl Nitrate-Nitric Acid-Water-TBP**, J. Durandet, et al., France.

1175 **Disposal of the Radioactive Effluents at the "Commissariat a l'Energie Atomique" Treatment Leading to Evacuation into a River**, M. M. Duhamel, et al., France.

1176 **Experiments on the Incorporation of Conc. Solutions of Fission Products in Glasses and Micas**, Bonniaud*, et al., France.

1177 **Process for Retention and Recovery of the Uranium Contained in Liquid Effluents**, P. Pagny, France.

1196 **Enrichment of Depleted Uranium in a Gaseous Diffusion Plant**, Lagrange*, et al, France.

1259 **Preparation of UF_4 from UO_3 or Uranyl Salts**, J. Sanlaville, France.

1260 **Improvement in the Manufacture of Uranium—Double Fluoride Cycle**, M. Brodsky, et al., France.

1261 **Production of Heavy Water in France**, E. Roth, et al., France.

1263 **Exp. Values of the Sep. Factor for U Isotopes in the Gaseous Diffusion Process**, O. Bilous, et al., France.

1264 **Economics of Gaseous Diffusion Plant Design**, O. Bilous, France.

1273 **Friction of Carbon in Dry Gases**, J. Millet, et al., France.

1275 **Multi-ton Production of Fluorine for Manufacture of UF_6**, A. P. Huber, et al., U.S.

1676 **Treatment of Radioactive Effluents at the Mol Laboratories**, P. Dejonghe, Belgium.

1719 **Chemical Processing of Uranium Ores in Hungary**, M. Fodor, et al., Hungary.

1740 **Reduction of U from CO_3 Solutions with H_2 Using UO_2 as Catalyst**, B. Bunji, et al., Yugoslavia.

1781 **Techniques for Estimating Cost Savings in Industrial Uses of Radioisotopes**, P. C. Aebersold, et al., U.S.

1831 **The Use of Nuclear Energy for Purposes other than the Generation of Electricity**, W. H. Zinn, U.S.

1837 **Chemical Processing of Two-Region Aq. Homo. Reactors**, W. D. Burch, et al., U.S.

1851 **Application of Anion Exchange to the Reprocessing of Pu Fuels**, M. T. Walling, Jr., U.S.

1913 **Feasibility of Radioactive Waste Disposal in Shallow Sedimentary Formations**, J. W. Watkins, et al., U.S.

1969 **Corrosion of Metals by Molten Fluorides**, J. H. Devan, et al., U.S.

2023 **Determining Small Amounts of Impurities in Pure Substances by Radioactivation Analysis**, Y. D. Yakovlev, et al., USSR.

2196 **Investigations of UO_2 and PuO_2 Chlorination with CCl_4**, I. V. Budayev, et al., USSR.

2231 **Separation of Individual Rare Earth Elements**, D. I. Ryabchikov, et al., USSR.

2253 **Dry Method of Regeneration of Irradiated Uranium by Gaseous Fluorine**, V. Prusakov, et al., USSR.

* No initials given.

Nuclear Fuel Processing

a challenge for the future

Efforts by the AEC to attract private industrial participation in the irradiated nuclear fuel processing field have been "singularly unsuccessful." This contrasts with other portions of the nuclear energy business, for example, manufacture of fuel elements or reactor components, where industry participation has become increasingly significant. In view of the generally agreed future growth of nuclear energy use in the United States, and the professed desire *(1)* of the AEC to attract industrial participation in the fuel processing phase, it seems appropriate to consider two aspects:

The technological status of the field at present and that expected within the near future.

The apparent anomaly of the lack of industrial interest at this time, and a consideration of the factors necessary to provide for eventual industrial participation.

To answer these questions the author conducted a panel discussion symposium at the A.I.Ch.E. Cincinnati Annual Meeting. The session featured two four-man panels whose work is reported here.

J. L. Schwennesen

Idaho Operations Office—U. S. Atomic Energy Commission

PANEL A: Future chemical and engineering potentialities

That the so-called "aqueous" methods of treating and decontaminating irradiated fuels "are destined to remain the major chemical processing methods for reprocessing of spent fuels from power reactors" because of their flexibility, high efficiency, and advanced engineering status was proposed by panelist Hill (2). He provided an extensive historical review and analysis of precipitation, solvent extraction, and ion exchange processes employed to recover irradiated fuels. Further process refinements and improvements in aqueous processes were projected on the basis of experience and research and development work currently underway. Hill stated that recent advances in the technology of solvent extraction processes make it almost a certainty that solvent-extraction processes can be devised which can provide adequate separation from fission products in one cycle, particularly when coupled to other necessary processing steps for final decontamination. He also concluded that the "close coupled" processing plant (to a single reactor) would probably not normally be economically competitive with a centralized processing plant serving many reactors.

The aqueous processing field was considered by panelist Slansky (3) from a more specific point of view. He expressed the desire to achieve a consolidation of aqueous processes so that many varieties of irradiated fuels differing widely in composition and uranium enrichment levels could be processed by means of a single, or relatively few separate process chemistry schemes. Since the solvent-extraction step for decontaminating fertile or fissionable material is similar for all irradiated-fuel solutions, the problems in developing a *universal* process are chiefly those related to development and use of a *universal* fuel-dissolution reagent. According to Slansky, significant progress is being made in this direction. Most irradiated fuels can probably be dissolved

by either a nitric-hydrochloric, or a nitric-hydrofluoric acid reagent. Such fuel solutions, with perhaps some composition adjustments, appear capable of being handled in conventional solvent-extraction equipment. Progress is being made in solution of the material-of-construction problems for the fuel-dissolving steps.

The potential for reducing capital investment costs of aqueous processing plants was stressed on the panel by Baczewski (*4*) since present high costs are a deterrent to industrial participation. His thoughts were linked to the conceptual design of the AEC Reference Fuel Processing Plant (*5*), Figure 1, which includes multiple head-end fuel-dissolving facilities, three cycles of solvent extraction and various auxiliary features. He pointed out that reduction in the number of head-end dissolving facilities is a prime area in which to strive for cost reduction because of the large investment required for such facilities; similarly, a reduction in the number of solvent-extraction cycles would offer an appreciable saving. The possible technical feasibility of both of these approaches was discussed by previous panelists. Baczewski foresaw relatively little potential monetary saving in plant construction costs by improved or sharpened design or construction practices *per se*.

The case for nonaqueous fuel recovery processes was presented by panel member Levenson (*6*), who explained that knowledge and experience of these methods is meager when compared to aqueous systems. This very lack of knowledge coupled with generally excellent performance of aqueous processes sometimes raises mental barriers toward consideration of nonaqueous systems for future plants. However, the potential value of nonaqueous processes relates to the entire fuel cycle, not merely the fuel-processing portion, and includes such potential advantages as "shorter (fuel) cooling time; therefore, lower inventory charges and lower capital costs for fuel storage facilities, . . . less stringent critical mass design requirements, . . . compact (processing) plant in conjunction with a single reactor, . . . recovering alloying ingredients (of fuel)."

Fission products, Levenson contends, can probably be removed and contained in considerably smaller volumes than is possible with aqueous processes. He questions whether aqueous processes will be economical enough, in terms of the entire fuel cycle, to make a sufficiently low contribution to the cost of nuclear power. It is clear that he does not think so, and that he believes that nonaqueous processes have sufficient over-all potential to warrant continued, intensive development efforts.

The close-coupled processing plant

In response to a request for elaboration regarding his opinion that the "close-coupled plant is unlikely to be economically feasible," Hill in-

PANEL A: O. F. Hill, manager, Chemical Development, Hanford Labs, GE; C. M. Slansky, chief, Chemical Development Section, Atomic Energy Division, Phillips Petroleum; K. C. Baczewski, project process engineer, Chemical Plants Division, Blaw-Knox; and Milton Levenson, associate chemical engineer, Argonne.


SLANSKY


HILL

BACZEWSKI



LEVENSON

... Fundamentally, it is too early to make any sort of definitive cost comparisons between aqueous and non-aqueous methods.

dicated that he was referring specifically to aqueous-type processing plants. On the basis of projections of the most favorable economics to a plant embodying the technological advances forecast in his paper, Hill concluded that to avoid excessive processing costs, a plant with a throughput of 1 to 2 tons of natural or slightly enriched uranium per day appeared to be a minimum capacity plant. Individual reactors do not discharge a sufficient volume of fuel to meet this capacity requirement.

In partial rebuttal Slansky suggested that a close-coupled plant might really be little more than "a laboratory-scale operation." As such, the actual capital cost of a close-coupled plant would vary markedly from the classical 0.6-power relationship with capacity. He felt that instead of the investment cost for a large processing plant, the cost for a small scale, close-coupled plant might be in the range of that to be expected for a "hot cell" operation. Under such conditions a different economic picture with respect to operating costs, analytical costs, etc. would result. Also cited by Slansky, as important contributing factors, if his figures are correct, is the opportunity for industry to enter the chemical processing field at relatively low investment cost. He also noted that factors other than strict economics may be involved, i.e., familiarization potential for industry, potential by-product values, potential reduction in fuel shipment problems, etc.

Estimated "total" cost of AEC reference plant

The AEC Reference Processing Plant *(5)* is assumed to be located at an existing AEC site and to use a number of existing auxiliary facilities (laboratory, power-house, water-supply system, etc.). The estimated cost was questioned if constructed "on a vacant lot," with the necessity of providing all needed facilities. Baczewski, although prefacing his remarks with the observation that he knew of no detailed estimates, suggested that the Reference Plant cost would probably be in the $30,000,000 range under such conditions (as compared to the $20,000,000 reference cost used by the AEC in determining fuel processing costs for reactor operation). He observed also that the potential capital cost reductions projected in his paper would, if achieved, also proportionately reduce the cost of auxiliary facilities.

Relative processing costs—Aqueous vs. non-aqueous methods

Fundamentally, it is too early to make any sort of definitive cost comparisons between aqueous and nonaqueous methods. Nonaqueous plants cover a wide spectrum of potential capabilities, with fuel decontamination factors ranging from very low (for certain of the pyrometallurgical processes) to very high, even higher than conventional solvent-extraction processes for certain of the volatility processes. What preliminary information is available, according to Levenson, suggests that capital costs for the nonaqueous plants may turn out to be roughly similar to those for solvent-extraction plants. However, nonaqueous processes may offer overall fuel cycle cost benefits such as lower inventory charges, less stringent critical mass requirements, etc., as outlined earlier.

Acceleration of nonaqueous process development

At the present time there is no good method for determining the relative amount of effort which should be expended for either aqueous or nonaqueous process development. If, as may well be the case, essentially all of our reactor megawatts are tied up in programs for the production of weapons materials, then aqueous process development should continue to receive essentially all the research and development money. If, on the other hand, power reactors and economics are to become important, nonaqueous processes should receive more support than they are presently receiving.

The type of fuel-reprocessing system depends upon the type of reactor used (an aqueous homogeneous reactor obviously would not employ nonaqueous processing methods) and must be considered in terms of the economics of the entire fuel cycle.

Custodial storage of wastes

In considering methods for custodial storage of radioactive wastes from either aqueous or nonaqueous processes, it appears that one may be approaching the limiting situations, of storage of fission products plus a relatively small quantity of extraneous materials. This may be the case because the nonaqueous waste volumes are inherently small to begin with, while current aqueous technology indicates that waste volumes can be materially reduced after formation. Thus, though there undoubtedly will be cost differences between processes, technologically speaking it appears that the custodial storage problem *per se* may be similar in magnitude. Levenson observed that certain pyrometallurgical process slags containing fission products might conveniently be cast into a block of stainless steel, thus achieving "a fairly good custodial situation."

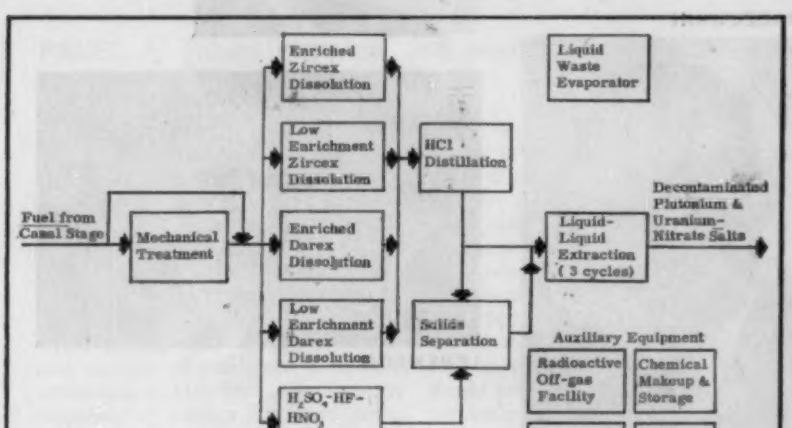

Figure 1. The block flow diagram of the AEC reference fuel reprocessing plant.

STOCKMAN

STOLLER

BURMAN

GUNYOU

PANEL B: C. H. Stockman, manager, Research Operating, B. F. Goodrich Res. Center; E. B. Gunyou, chief of operations, Atomic Energy Engrg., Alco Products; S. M. Stoller, engineering manager, Vitro Engrg.; and L. C. Burman, manager, Atomic Energy Devel., Engelhard Indust.

PANEL B: When and under what conditions may private industry participate?

A sufficient volume of irradiated fuel would be available between 1965 and 1970, Stockman *(7)* estimated, to allow a private firm to enter the field with reasonable assurance of being able to make a profit on the required investment. Emphasizing the principle that a stockholder's equity should not be diluted, that is, that new plant investments should not normally be made unless the current average rate of return on investment can be realized, he indicated that the profit level on investment in the chemical industry is relatively high, averaging in the neighborhood of 15% after federal income taxes. Thus, a relatively large load is required to make nuclear fuel processing attractive to the chemical industry while at the same time providing unit-processing costs low enough to be of economic interest to the builders and operators of nuclear power plants. Stockman presented an analysis (Table I) of the likely future annual dollar volume of processing business based upon the McKinney Report, Series II.

"From the standpoint of fabrication, handling, and use," Gunyou *(8)* contended, "atomic fuels have the general characteristics of expendable spare parts. " Thus "the volume of production of *like* items, rather than total volume, is a major factor in determining unit costs and, in turn, net fuel costs." Standardization of specifications, including minimum standards to avoid "over-specification" at each step in the fuel fabrication or processing operations, can be more important in cost reduction than total volume of fuel being handled. In formulating his answer to the hypothetical question, "What is the required scale of operation with a *standard* fuel element?" Gunyou concluded that economics would dictate that the operator of a "nuclear-fuel service" plant would require "standard-fuel business from about 700 emw of (nuclear) power capacity." His estimates were based upon specified assumptions including use of a standard low-enrichment, uranium oxide fuel capable of achieving burnup in the range of 5000 to 10,000 mw. d./t. in relatively large nuclear power plants.

Table I. Potential Fuel Processing Business from Private Power Reactors

Year	Nuclear capacity,[a] 10^6 kw.	Annual dollar volume of processing business[b]
1960	0.8	\$5,260,000
1965	2.9	19,050,000
1970	7.2	47,300,000
1975	22.6	148,500,000
1980	54.6	357,000,000

[a] Based on McKinney Report Series II.
[b] At 75% load factor and one mill/kw.-hr. allotted to chemical processing.

From the business risk point of view, the operation of nuclear fuel-processing plants brings many special problems to industry, according to Stoller *(9)*. The problem of obtaining insurance covering operation of processing plants has not been considered in detail. Stoller suggested that some variation of the "relative rating system" now being considered by insurance companies for establishing insurance rates for power reactors might also be applicable to separations plants. It is probable that a large sinking fund would be required to assure funds for "perpetual care" of radioactive waste-storage facilities in the event that industrial responsibility for wastes would extend for a prolonged period. He also suggested that waste disposal facilities be considered for depletion allowances "on the basis that the land reserved for storage is rendered unfit for other use."

The AEC should modify its invitation for industrial participation to specifically indicate its willingness to consider an industry proposal for a "single purpose" plant suggested Burman *(10)*, since there appears to be a trend toward use of uranium oxide fuel loadings. Government facilities presumably would continue to be used for other types of fuels not capable of being handled in the single purpose plant. He also suggested continued or accelerated research and development activity by the AEC in the fuel processing field, assurance by the Commission that it will not compete with industry in the sale of fission products, and use by the Commission of private facilities for such other services as "cold" fuel scrap processing, where appropriate. Burman felt that AEC acceptance of responsibility for control of radioactive wastes shortly after these have been generated in a private plant would be a necessity. In this connection, he suggested that the Commission consider the offering of plant-operating space to industry on government reservations, to facilitate delivery of wastes to government control.

The following thoughts were se-

continued

continued

lected from a number of interesting items discussed by the panel.

Influence of the long-range picture upon fuel processing

Several thoughts related to W. K. Davis' prediction of the growth of nuclear power — that shortly after the turn of the century nuclear energy would contribute to U.S. power needs the approximate equivalent of the total generated from all sources today. This large potential growth prompted questioners to ask about industry's approach in terms of investment for research and facilities within the near future. Two of the panelists *(7,8)* reached similar conclusions — that there is an insufficient volume of business to attract industry at present, and that the "marginal period" is probably at least seven years away. Gunyou stressed that industry must be able to see where it is going before committing large investments.

Although the outlook for industrial participation in fuel processing responsibilities seems assured eventually, the present situation (which involves fuels of many diverse types, coupled with a certain amount of technological uncertainty as to which fuel recovery processes may be most attractive in the long run) makes it extremely risky for industry to invest its dollars unless plant payout is very rapid. Gunyou observed that the fuel cycle deserves an amount of government assistance proportionate to that given industry toward reactor development, to stimulate industrial participation. The panel generally agreed that the long-term outlook for the industrial processor appeared bright, with most "participation" problems falling within the period of the next 5 to 15 years.

Industrial interest in a "close-coupled" processing plant

Tentative explorations with some utilities in power reactor planning have indicated antipathy on their part toward an integrated reactor-processing plant complex. In addition to the unfavorable processing economics of the close-coupled plant for many reactor concepts under consideration, there appears to be an intuitive reluctance by industry to face the additional problems which a processing plant might bring, such as, disposal of high level liquid radioactive wastes, insurance complications, etc. On the other hand, in certain cases such as the breeder reactors, there may be significant savings involved in the entire power plant complex resulting from integral processing which make the idea attractive. Because of his belief that plant investment costs are likely to be very high to allow the processing of *any* amount of irradiated fuel, Gunyou concluded that a close-coupled plant probably would require fuel from about 500 eMw of power capacity to be economically attractive. The panel agreed that because of the several interesting and potentially attractive features, the concept deserved more thorough examination.

Availability of government-owned fuel to an industrial processor

The original AEC invitation for industrial participation offered a specified quantity of fuel for processing, for a guaranteed period of five years. The question was raised as to whether extension of the guarantee time alone would be of any particular benefit to industry at this time. Stockman indicated that increasing the guarantee period *per se* would be of little benefit unless a larger volume of fuel could be provided. He stressed again his conclusion that the fundamental problem is one of achieving a profit in the short-term future on the large investment required for fuel processing facilities. A hypothetical 10-year load guarantee if of sufficient magnitude would end in the period near 1970 at which time, according to Stockman's conclusions, there would be opportunity for at least one processing plant to make a profit on the basis of an industrial load alone.

The AEC "interim" fuel processing charge

A feature of the AEC interim fuel processing program is that it is intended to provide processing services until industry is able to provide a similar service at "reasonable" cost. Reasonable costs were tentatively defined as approximately 15% above AEC costs, based upon the Reference Fuel Processing Plant *(5)* concept. Burman *(10)* and others suggested that AEC charges are unrealistically low (from the standpoint of an industrial processor providing a similar service). Since the stimulation of industrial participation in reactor design, construction, and operation is an AEC objective, the question was raised as to whether or not any increase in processing charges (such as might follow from Burman's suggestions) would affect the reactor development program. The panel felt that since chemical processing costs are not controlling elements in fuel cycle costs, and therefore probably have only a minor influence on the status of reactor programs, that the Commission might take a "more realistic" look at its assumed processing costs, to stimulate industrial participation in the processing field.

Responsibility for high level radioactive wastes

In view of the potential fission-product values in radioactive wastes, the question was asked whether an industrial fuel processor would prefer to have the government accept title to wastes as soon as generated in an industrial plant. This proposal can be compared to an alternate one in which wastes would be owned by industry for a finite time, to allow the extraction of potential values, before delivery to government ownership. The latter course of action has been contemplated by the AEC, the finite time being twenty years. The panel was unanimous in agreeing that industry prefers to be relieved of the problem at the earliest practicable moment, without concern for potential fission-product values. It was pointed out that fission products at best, must compete with other irradiation devices, and that the future is too nebulous with respect to large-scale fission product use to permit much consideration of this factor.

A number of pertinent thoughts were advanced as to why the radioactive waste disposal problem must ultimately, as expressed by Stoller, "remain a public problem — not a private company problem." In all probability, when an industrial fuel processor delivers radioactive wastes to government control, some charge would be expected by the government to the processor in recognition of the "perpetual care" that will be required.

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3. Slansky, C. M., "The Universal Process for Nuclear Fuel Recovery," *Ibid*
4. Baczewski, K. C., "Capital Cost Reductions in Aqueous Processing Plants," *Ibid*
5. "Summary Report: A.E.C. Reference Fuel Processing Plant," USAEC Report, WASH-743 (October, 1957).
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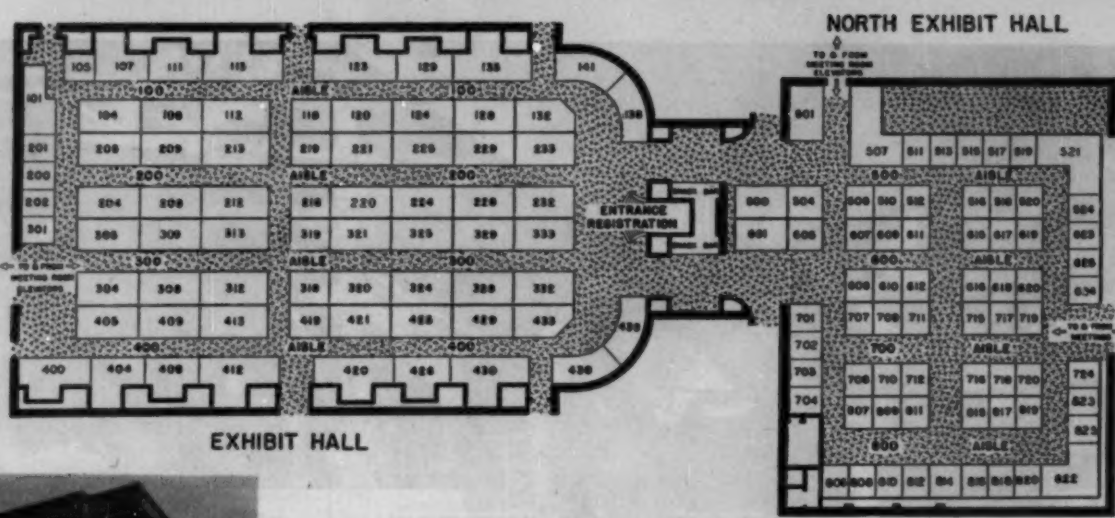
For more information, turn to Data Service card, circle No. 46



'59 NUCLEAR CONGRESS and Atomfair

Cleveland, Ohio – April 5-10

- **5th Nuclear Engineering & Science Conf.**
- **5th Atomfair**
- **7th Hot Labs Conference—page 98**
- **7th NICB Management Conference**

In addition to technical symposiums and individual presentations of interest to a broad spectrum of chemical engineers, the proceedings at the 1959 Nuclear Congress, starting on April 5 in Cleveland, will feature several special events worthy of note. Arthur Compton, of Washington University, will address an A.I.Ch.E. Lunch on Tuesday, 12 Noon, in the Empire Room of the Sheraton-Cleveland Hotel. Speaker at the All Congress Banquet on Wednesday evening is yet to be announced.

The Meeting will have a pronounced international flavor—present will be specialists from England, France, and Italy, and invitations have been extended to leading Russian engineers.

Below, are detailed programs for the technical sessions and a list of exhibitors at the Atomfair. No advance details are available on the Atomic Energy Management Conference, with morning and afternoon sessions on Wednesday, Thursday, and Friday. However, the sponsors, the National Industrial Conference Board advise that the discussions will center on the broader applications of nuclear power, and the influence of the nuclear field on the sociological and economic structure of industry.

Nuclear Conference Program

MONDAY, APRIL 6—9:30 A.M.

WASTE DISPOSAL

Initial Performance of Shippingport Radio. Waste Disposal Plant, J. R. Lapointe, et al., Westinghouse.

Design Princ. for Dispos. React. Fuel Waste into Underground Salt Cavity, Shosei Serata & E. F. Gloyna, Univ. of Texas.

Propnl. Sampling of Flowing Liquid Wastes for Radio. Monitoring, J. M. Ruddy, Brookhaven.

Thermal Consid. in Stor. of Radio. Wastes in Salt Formation, R. S. Schechter & E. F. Gloyna, Univ. of Texas.

Disposal of Radio. Liquids from Nuclear Powered Ships, J. M. Smith, Jr., G-E.

Need for Biol. Monitoring of Radio. Waste Streams, by R. F. Foster, G-E, Hanford.

NUCLEAR RESEARCH TEST & TRAINING FACILITIES

Radiol. Health Training re Water Quality, D. W. Moeller, et al., Taft San. Eng. Center.

Design Consid. for In-Pile Loop, C. A. Baumgartner, Curtiss-Wright.

Compar. Test Facilities—Aircraft Propulsion Systems, E. O. Johnson, Marquardt Aircraft.

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Instr. for Reactor Transient Study Program of KEWB React. E. L. Gardner, et al. Atomics Intern.

Critical Exper. Safety Systems with Electrometer—Type Opernal. Amplifiers. R. Ball. B & W.

Simulation of EBWR for Geneva Conf., R. A. Brey, L & N.

Transistorized Computers for Naval React. Instr. Systems, W. Alexander, Stromberg-Carlson.

Approx. Solns. to React. Kinetic Equations for Ramp Inputs, J. MacPhee, AMF Atomics.

Low Const. Nucl. Power Plant Simulator, C. C. Scott, Minneapolis-Honeywell.

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Emergency Proc. for Accidental Disch. of Liquid Radio. Wastes from a Reactor, E. D. Harward. AEC-Pitts. Naval Reactor Operns. Office.

Meas., Building Penetration, & Water Filter Passage of Radioactivity, C. G. Bell, Jr. ORNL.

Deter. Water Potability Following Nuclear Attack, G. Klein, Univ. Calif.

Assembly & Oper. of Low Level Counting Facility, G. R. Hagee, Taft San. Eng. Center.

Radioactivity in Water-Environ. Surveillance, H. P. Kramer, et al., Taft San. Eng. Center.

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Des. & Dev. of 600°F. Pulse Pre-Amplifier for Nuclear Instr., W. L. Frisby & E. M. Palmer, GE, Burlington, Vt.

Dual-Channel React. Protect System for Nucl. Pwr. Plants, A. S. Bartu, G-E San Jose, Calif.

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Stresses in Hollow Cylinders Due to Assymmetrical Ht. Generation, H. Kraus & O. Sonnemann, Westinghouse.
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Alteration of Gamma Cell for Pu—Gamma Usage, H. M. Glen, ORNL.
Bases for Estab. Nucl. Safety Criteria, N. Ketzlach, GE, Hanford.
History of Occupational Expos. to U Air Contam. in Feed Mtls. Prod. Facil., A. J. Breslin & W. B. Harris, AEC—Health, & Safety Labs.
Validity of Film Badge & Pocket Chamber Records in Eval. Radia. Expos. of Personnel, H. Blatz, Dept. Indust. Med., N. Y. Univ.
Contrib. to Gonadal Dose by Med. & Dental X-Rays, J. S. Laughlin, et al., Sloan-Kettering.

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Deter. Local Ht. Tr. Coef. by Transient Technique, B. A. Stanley & J. B. Conway, GE, Evendale.
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Invited Paper, J. Haarer.
Transistorized Pwr. React. Safety System, H. H. Hendon.
Digital Startup Control for Air-Cooled Nucl. Reactors, S. N. Lehr, GE—Cincinnati.
Magnetic Automatic Power-Range Control for Aircraft Nucl. Reactor, S. P. Hemmenway et al., GE—Cincinnati.
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Radiochem. Reprocessing Costs in Expanding Nuclear Economy, C. E. Guthrie, ORNL.
Develop. in Reprocessing Irradiated Nuclear Fuels by Pyrometallurgical Methods, L. F. Coleman, et al., Argonne.
Develop. in Feed Preparation and Solvent Extraction, R. R. Bruce, et al., ORNL.
Production of Pure UF_6 from Ore Concentrates, W. C. Rush, et al., Allied Chem.
Chemical Methods for Nuclear Reactor Decontamination, J. L. Zegger & G. P. Panzer, Alco.

POWER REACTOR DESIGN

Design of Daniels-Boyd Nuclear Steam Generator for 400 MW (net e) Power Plant, W. Boyd, et al., Eng. Inst. of Canada.
Evolution of Army Package Power Reactor Family, J. G. Gallagher, Alco.
Design of 10 MW (e) Sodium-Deuterium Reactor Power Plant, E. D. Oppenheimer, et al., Nuclear Develop. Corp.
Potential of Heavy Water Reactors Employing Organic Coolant, M. J. McNelly, Canadian GE.

INSTRUMENTATION

Effects of Reactor Exposure on Boron-Lined & BF_3 Proportional Counters, W. M. Trenholme, GE—Lynn.
System Design for Improved Water Level Control of Steam Generators, D. P. Waite, GE—Lynn.
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Design and Operation Considerations for Off-Gas Systems in Nuclear Processing Plants, L. R. Michels, GE—Hanford.

Evaluation of Design and Performance of Thorex Plant, G. S. Sadowski & W. R. Winsbro, ORNL.

Design & Operating Performance at Idaho Chem. Process. Plant, A. L. Ayers & F. M. Warzel, Phillips Petr.

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Measurement of Gear Wear by Activating Wear Particles in Lubricant, H. D. Briggs, GE—Schenectady.

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Investigation of Sodium Phosphate Hide-out in Boiling Water Using P-32, J. W. Stout, Jr., Balt. Gas and Elec.

Radio Tracer Study of Flow Patterns in Fluid Coker, J. M. Ausman, et al., Esso Res. & Eng.

REACTOR PHYSICS

Nuclear Analysis of Small Thermal Homogenous Critical Assemblies, G. P. Rutledge, et al., Westinghouse.

Nuclear Calculation for Continuously Fueled Pebble Bed Reactor, R. O. Bagley, Alco.

AEC Reactor Physics Program, W. C. Bartels, AEC.

Sodium Graphite Reactor Stability Analysis, J. Reichman, Atomics Int.

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Fabrication of Tubular Fuel Elements, S. Megeff & J. L. Zambrow, Sylvania-Corning Nucl.
UO_2 Ceramic Fuel, R. M. Powers, Sylvania-Corning Nucl.
Rate of Alloying SRE Metal Fuels with SS Above 1500° F, R. S. Neymark, Atomics Int.
Irradiation of Fuel Elements Containing UO_2 Powder, J. L. Bates, GE—Hanford.

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Controlling Thickness of Plastic Film Using Beta Ray Gauges, G. C. Wiggins, Dow Chem.
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Operg. Experience with Instruments Using Radioisotopes in Process Industries, R. C. Kimball, Amer. Viscose.
Meas. Liquid Density Using a Beta Source, E. J. Preh & C. Kearns, Indust. Nucleonics.
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Hunterston Project & Future Devel. of Gas-Cooled Power Reactor, K. J. Wootton, Kent, England.
Berkeley Power Station & its Influence on Future Devels., A. L. Shaw, AHWC, AMIEE.
Multipurpose Reactor for Spain, B. K. Winkleblack, Atomics International.
Status of Nuclear Power in Italy, F. Ippolito, Rome, Italy.

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Marcoule's Reactors G.2 and G.3—Some Features
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BIGGEST YEAR

In its twenty-eighth year of shipbuilding—twenty years after incorporating as The Ingalls Shipbuilding Corporation—Ingalls set an unprecedented pace in the construction and repair of shallow draft vessels.

During the past 12 months, Ingalls' shipyard at Decatur, Ala.—largest and busiest on the Tennessee River—not only turned out great volume but demonstrated its ability to design and construct highly specialized vessels. Among these were: an insulated caustic soda barge for Westvaco Chlor-Alkali Division of Food Machinery and Chemical Corporation, a sulfuric acid barge for Consolidated Chemical Industries Division of Stauffer Chemical Company, 12 new hopper type barges for Seley Barges, Inc., and a Diesel-powered patrol boat for the U.S. Engineers. Many conventional type vessels were also delivered.

THE INGALLS SHIPBUILDING CORPORATION

Executive Offices: Birmingham, Alabama, U.S.A. • **Shipyards:** Pascagoula, Miss. (Two yards on the Gulf); Decatur, Ala. (On the Tennessee River)

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Present Status of Thermonuclear Research, A. E. Ruark.
Problems of Fusion, J. L. Tuck.
Survey of Fusion Processes, R. F. Post.
Design & Opern. of a Shunt Regulated 25,000-Joule Inductive Energy Storage System, R. L. Gamblin, Forrestal Res. Center.

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Fabrn. of Tubular U Fuel Elements, C. E. Polson, et al., National Lead.
Fabrn. of Urania Dispersed in Graphite Fuel Elements, J. H. Handwerk, et al., Argonne.
Tensile Creep of Pure and U-Loaded Graphites, L. Green, Jr., et al., Aero-Jet Gen.
Use of Isostatic Pressure Techs. in Fabrn. of Fuel Elements, J. Fugardi & J. L. Zambrow, Sylvania-Corning Nucl.
Segregation in Al-13% U Castings, D. Peckner, Westinghouse.
Swelling of Irradiated U-Zr Alloy During Temp. Transients, W. V. Johnston, Knolls.
Effect of Metallic Impurities on Props. of U and 2 w/o Mo-U Alloys, J. M. Dickinson & E. E. Zukas, Los Alamos.

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Sinterability of UO Powders for Fuel Elements, R. B. Wrinkle, Mallinckrodt.
Mechanism of Sintering Ceramic Mtls., R. Chang, Atomics Intern.
Forge Rolling Zircaloy Components, R. D. Johnson, Clevite Res. Center.
Irradiation-Induced H_2 Absorption by Ni-enriched Zircaloy-2, W. Yeniscavich, et al., Westinghouse.
Ultrasonics in Testing of Irrad. Fuel Elements, J. M. Fouts, GE, Hanford.
Devel. of Nucl. Rad. Resistant Fluids and Lubricants, W. L. R. Rice & D. A. Kirk, Wright Air Devel. Center.
Na Corrosion as Function of Time, J. M. McKee, Nucl. Devel. Corp.
Purification of Li by Vacuum Dist., W. Arbiter & S. Lazerus, Nucl. Devel. Corp.

REACTOR OPERATING EXPERIENCE AND MAINTENANCE

Extended Zero Power Experiments on APPR-1 Core, S. D. Mackay, Alco.
Operational Problems of Original Hanford Reactors, J. R. Young, GE, Hanford.
Radioactivity Buildup in Primary Systems of APPR, W. S. Brown, Alco.
Detection of Na Leaks in SDR, H. Steinmetz & R. Winkelstein, Nucl. Dev. Corp.
Inspection & Maintenance Experience with HRE II, D. M. Shepherd & C. W. Collins, ORNL.
OMRE Operating Experience, N. J. Swanson & D. R. Muller, Atomics International.

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The Arithmetic of Materials Handling

Fuller Airveyor unloads wood flour to two forty-five foot silos. Second Airveyor system reclaims material 360 feet to processing.

General Electric Changes From Bags to Airveyor ... Cuts Handling Costs 60%

As part of a program to increase plastics production and reduce operating costs at its Pittsfield, Mass. plant, General Electric Company called in Fuller engineers to design systems for handling wood flour in bulk.

Wood flour—used as a filler in phenolic molding compounds—was being handled in 75 and 100-pound bags. Unloading one carload of bags required 16 manhours. Bags were loaded on dollies and wheeled to a distant elevator.

SAFETY FIRST—The two pneumatic Airveyor® materials handling systems, engineered and manufactured by Fuller Company, were installed by its parent company, General American Transportation Corp., providing undivided responsibility. This installation resulted in a 60% saving in handling costs! The two systems are handled by one full-time and one part-time operator. Manhours to unload one car have been reduced from sixteen to six!

In addition, all equipment is designed to conform to strict safety specifications set down by G-E engineers.

FLOW *YOUR* MATERIALS—The Airveyor is a system that flows your material through sealed pipes. It's fast, safe, and self-contained. The pipes can be placed close to ceilings, run underground or through walls.

Whether you process wood flour—or other dry granular materials—look into the many economies of Airveyor conveying. Write today for interesting, detailed literature on Airveyor and other Fuller pneumatic materials handling systems.

FULLER COMPANY GENERAL AMERICAN TRADE MARK

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pioneers in harnessing AIR

FULLER COMPANY
174 Bridge St., Catasauqua, Pa.
SUBSIDIARY OF GENERAL AMERICAN TRANSPORTATION CORPORATION
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G-196
1304

"See Chemical Engineering Catalog for details and specifications".

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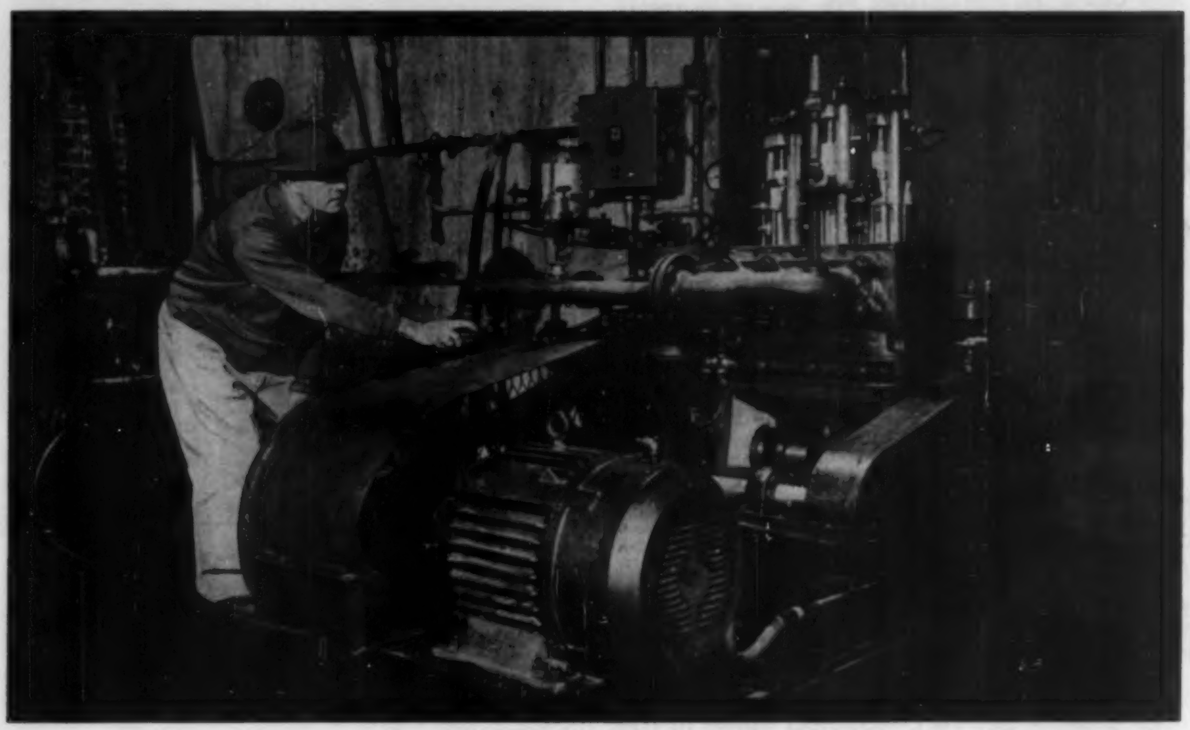

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Mixers, top or bottom-entering (p. OBC). Turbine, propeller, and paddle types, 1 to 500 hp. Bulletin 102 from Mixing Equipment. **Circle 64-1.**

Mixers, turbine-type (p. 85). General Turbo-Mixer Bulletin from Turbo-Mixer Div., Gen. Amer. Transportation. **Circle 46-1.**

Moisture Tester (p. 162). Technical Bulletins, application data from C. W. Brabender Instruments. **Circle 17.**

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Nozzles, spray (p. 158). Comprehensive Catalog 5600 from Binks Mfg. **Circle 14.**

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Piping, plastic (p. 6). Bulletin CE-50 from Amer. Hard Rubber gives properties, chemical resistance, costs of 11 plastics and rubber materials, Selector Charts. **Circle 3.**

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Pumps, chemical (p. 115). Teflon bearing seals now standard on Series H-2 Durcopumps. Details from Duriron. **Circle 31.**

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Pumps, leakproof (p. 155). Pump and motor in single unit. Data from Chempump. **Circle 21.**

Pumps, peristaltic-action (p. 152). Complete data on sizes and capacities from Sigmamotor. **Circle 111.**

Pumps, vertical (p. 95). Bulletin from Peerless Pump Div., Food Mach. and Chemical, on "Hydro-Line" pumps. **Circle 109.**

Pumps, vertical (p. 126). Bulletin 203-7 is complete summary of acid and chemical pump data. Lawrence Pumps. **Circle 57.**

Pumps, vertical, corrosion-resistant (p. 34). Technical data in Bulletin 727-1 from Goulds Pumps. **Circle 47.**

Purification System, cooling water (p. 158). Data from Barnstead Still & Sterilizer. **Circle 118.**

Rotameters (p. 96). Bulletin 18RG from Schutte and Koerting describes "Safeguard" rotameter with PVC end fittings. **Circle 107.**

Screeners, whirlpool (p. 114). For powders, liquids, slurries, in 4 to 400 mesh sizes. Details from J. M. Lehmann. **Circle 61.**

Scrubbers, fume (p. 163). From 1,000 to 30,000 cu. ft./min. Bulletins from Heil Process Equipment. **Circle 50.**

Scrubbers, gas (p. 128). Gas capacities from 100 to 200,000 SCFM, dust loadings to 100 grains/cu. ft. Peabody Engineering. **Circle 81.**

Separators, entrainment (p. 4). Bulletin 21 from Otto H. York on performance of the Yorkmesh Demister. **Circle 98.**

Tanks (p. 136). New, 16-page Catalog from Littleford Bros. **Circle 60.**

Tanks, storage (p. 148). Bulletin and price info on stainless steel storage-mixing tanks. Hubbert. **Circle 51.**

Tanks, wood (p. 166). Data Handbook from Wendnagel. **Circle 120.**

Tower Packing, carbon (p. 99). Data from National Carbon on Intalox Saddles in carbon. **Circle 70-2.**

Valves, jacketed (p. 137). "Thermon" jacket claimed to cut cost by 75%. Data from Cooper Alloy. **Circle 23.**

Valves, lift-plug, non-lubricated (p. 111). For difficult liquids at high pressures and temperatures. Data from Cameron Iron Works. **Circle 26.**

Vessels, pressure (p. 153). Data from Ellicott Fabricators on "corrosion-controlled" storage and pressure vessels. **Circle 37.**

Vibrators, bin (p. 144). Catalog Data from Syntron. **Circle 87.**

Weigher, continuous (p. 119). Bulletin 958 from Stephens-Adamson. **Circle 88.**

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

EQUIPMENT

301 Analyzers, continuous-stream. Industrial pH equipment, gas chromatographs, infrared analyzers, oxygen analyzers, detailed in new Catalog from Beckman/Scientific and Process Instruments Div.

302 Blowers, rotary-positive. New Bulletin from Sutorbilt Corp. gives specifications, performance data on rotary positive blowers and gas pumps.

303 Centrifuge, high-capacity. New, improved design of Merco centrifuge using higher rotor speeds, claimed to handle up to 600 gal./min. with sub-

continued on page 108

MATERIALS

358 Acids and Anhydrides. Two Brochures in one from Union Carbide Chemicals. Physical properties, solubilities, vapor pressures, azeotrope formation data.

359 Alloys, corrosion data. Booklet from Haynes Stellite contains charts and graphs showing penetration for special alloys in over 250 corrosives.

360 Chemicals, industrial. Booklet titled "Chemicals, Resins, Plastics," from Catalin Corp. of America describes the firm's plants, facilities and major products.

continued on page 108

SERVICES

377 Cleaning Service, process equipment. Complete acid cleaning service for any type of process equipment. Use of inhibitors said to preclude damage to equipment. Details from Dowell (Dow subsidiary).

378 Design and Construction, nuclear power plants. New Brochure from Atomics International describes an important approach to competitive nuclear-electric power.

379 Periodic Table Chart. Complete periodic table of the elements in color offered by Atomic Development Mutual Fund.

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

Equipment *from page 106*

stantial reductions in power requirements. Technical data from Dorr-Oliver.

304 Chromatograph, high-temperature. Bulletin from Consolidated Electrodynamics Corp. describes Type 26-203 which has maximum operating temperature of 500°C.

305 Clarifiers. New, 24-page Brochure from Process Engineers, Inc., covers line of Clarifier and Oxidator mechanisms for water, sewage, and industrial waste treatment.

306 Computers, digital. Application Report from Royal McBee Corp. describes use of the LGP-30 computer for heat exchanger design calculations at the Brown Fintube Co.

307 Controls, electric. Bulletin from Frank Electric Corp. describes design and fabrication of complete systems and individual panels for process instrumentation and control.

308 Controls, pH. Application Data Sheet from Beckman/Scientific and Process Instruments Div. gives details of an in-line pH control for continuous pressurized processes.

309 Dialysis Systems. Bulletin from Graver Water Conditioning Co. gives details of new system which can treat acid liquors.

DEVELOPMENT OF THE MONTH

HORIZONTAL MIXER BULLETIN
(Circle 601 on Data Post Card)

Young Machinery Co. announces a complete new line of horizontal mixers. Bulletin (12-pages) gives dimensions for mixers up to 500 cu. ft. working capacity and illustrates various arrangements of ends, supports, agitators, shafts, glands, covers, inlets and discharges, gates, and drives. The units can be furnished in carbon steel, stainless steel, or other alloy as required. For a copy of the new Bulletin, which includes a customer's check list for ordering purposes, Circle 601 on Data Post Card.

310 Dryers, electric and steam reactivated. Two Bulletins from C. M. Kemp Mfg. Co. give design details, specifications, dimensional data, utilities required.

311 Dryers, rotary-vacuum. Bulletin from F. J. Stokes Corp. lists capacities, heating surface areas, dimensions, weights, of 8 standard models, describes design features.

312 Evaporators, thermocompression. Mechanical Equipment Co. offers Bulletin describing units in standard sizes from 500 to 100,000 gal./day for production of fresh water from salt.

314 Filters. Corning Glass offers Bulletin on its new line of industrial filters. Structure, flow rates, thermal, chemical, and mechanical properties. Many charts.

315 Filter-Clarifiers. Bulletin from Hardinge Co. gives technical details, capacities, operating principles, operating data.

316 Filter Leaves. Bulletin from Multi-Metal Wire Cloth Co. gives complete design and construction data on filter leaves in metal and plastic.

317 Fittings, stainless steel. Revised Catalog from Tube Turns contains complete data on full line of stainless steel welding fittings and flanges.

318 Flowmeter, magnetic. Bulletin from Fischer & Porter. Also 5 Specification Sheets describing indicating and controlling instruments designed for use with the magnetic flowmeter.

319 Gauges, liquid-level. New, 8-page Catalog from Jerguson Gage & Valve Co. details complete line of gauges for remote liquid level indications.

320 Gauges, vacuum and pressure. Catalog and Price List from Hastings-Raydist gives complete details on all types of gauges and accessories.

continued on page 110

Materials *from page 106*

361 Cloth, wire. Bulletin from Unique Wire Weaving Co. describes weaves specially-designed for all types of industrial filters.

362 Coatings, protective. Revised Bulletin from Carboline Co. contains chart for selection of coatings according to service requirements.

363 Coatings, silicone-base. Properties, characteristics, applications of Sicon heat-resistant industrial finishes covered in Bulletin from Midland Industrial Finishes Co.

364 Fillers, diatomite. Technical Bulletin from Great Lakes Carbon, Mining and Mineral Products Div., is basic study of characteristics of diatomite mineral fillers. Also covers use as thermal insulation.

365 Hastelloy, alloy F. Good resistance to stress corrosion cracking. Bulletin from Haynes Stellite gives chemical composition, properties, rupture and creep test data, corrosion resistance.

366 Hydrides, metal. "The Mixed Hydrides," an 8-page review of selective reductions of organic compounds with complex metal hydride reducing systems is offered by Metal Hydrides Inc.

367 Molybdenum Hexacarbonyl. Bulletin from Climax Molybdenum gives physical and thermodynamic properties, preparation, chemical reactions, applications.

368 Paints, heat-resisting. Brochure from Joseph Dixon Crucible Co. includes 1,000°F temperature range reference chart of 7 different heat-resistant coatings, reactive characteristics, application details.

369 Plasticizers, epoxy. Newly-developed alkyl epoxyhexahydrophthalates claimed to have "built-in" stabilizing properties. Bulletin from Becco Chemical Div., Food Machinery and Chemical, gives preparation techniques, performance characteristics.

370 Propionaldehyde. Technical Information Data Sheet from Union Carbide Chemicals gives physiological, physical properties, storage, handling, shipping information. Vapor pressure and water solubility surves.

371 Reagent Chemicals. New 200-page Catalog and Price List from J. T. Baker Chemical Co. gives current specifications and prices for more than 1,300 reagents, other lab chemicals.

372 Resin, ion exchange. New ion exchange resin, Dowex Chelating Resin A-1, has high selectivity for heavy metal cations. Technical data and samples from Dow Chemical.

373 Silicones. New Reference Guide from Dow Corning gives properties and applications of more than 150 silicone products now commercially available.

374 Surface Active Agents, amphoteric. New, 32-page Technical & Product Development Data Catalog on amphoteric surface active agents made by Miranol Chemical.

375 Tantalum, high-purity. Technical Folder from National Research describes application of high-purity tantalum to chemical, electronic, and missile industries.

376 Vinyl Polymers and Copolymers. New Reference Book from Rubber Corp. of America includes technical specification sheets, application recommendations.

For more information, turn to Data Service card, circle No. 48

CEP's DATA SERVICE—Subject guide to free technical literature

CIRCLE CORRESPONDING NUMBERS ON DATA SERVICE CARD, PAGE 103

Equipment *from page 108*

321 Heaters, grid. Data from Rempe Co. on standard line of heaters featuring maximum heat transfer surface in limited space.

322 Indicator, motion. The "Roto-Guard" provides positive indication of drop in speed or stopping of machinery. Simple, positive, reliable, low-cost. Bulletin from Bin-Dicator Co.

323 Instrumentation, nuclear. Instruments and components for nuclear systems are covered in Bulletin from Consolidated Electrodynamics, Systems Div.

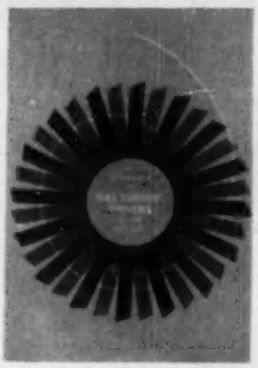
324 Instrumentation, nuclear. Technical Bulletin from Leeds and Northrup gives details of instrumentation for nuclear power reactor control systems. Also bibliography.

325 Laboratory Equipment, stainless steel. Specially designed for safe handling of radioactive materials, other hazardous substances. Folder from S. Blickman, Inc.

326 Laboratory Ware. New, 88-page comprehensive Catalog from Fischer & Porter gives details and prices on 377 glass items.

327 Mills, roller. Sprout, Waldron & Co. offers illustrated Technical Bulletin on one, two, three-pair high, and double roller mills. Complete specifications.

DEVELOPMENT OF THE MONTH



ECONOMICS OF GAS TURBINES
(Circle 602 on Data Post Card)

New Bulletin 166 from Clark Bros. Co. presents an analysis of the economic aspects of combustion gas turbine application to the refining industry. Special emphasis is given to turbine design and operating characteristics, and to the profitable use of its double function as a source of both power and heat. Described in Bulletin 166 are refinery applications involving pump and compressor drives, power generation, and emergency use. Also included are full performance charts on fuel consumption, exhaust gas flow, and heat recovery. For a copy of this unusual bulletin, Circle 602 on Data Post Card.

328 Mixers. Bulletin from Infilco gives selection tables, discusses theory of mixing.

330 Models, piping. Complete information from Industrial Models, Inc. on use of models as an engineering design tools.

331 Nozzles, spray. New line introduced by Schute and Koerting for discharging large quantities of liquids at low pressures. Bulletin gives capacity curves and dimensions.

332 Nozzles, spray. Spraying Systems Co. offers 48-page Manual on all types of nozzles in brass, steel, stainless, Monel, hard rubber, Uscolite, Teflon.

333 Piping, impervious graphite. Bulletin from Falls Industries describes new modular concept in impervious graphite pipe and fittings. Pressures to 75 lb./sq. in., temperatures to 340°F.

334 Piping, rigid polyvinyl chloride. Complete specifications and physical properties of normal and high-impact pipe, fittings, and valves in new Catalog from B. F. Goodrich Indust. Prod. Co., Plastic Products Div.

335 Positioner, all-electric. Will adjust, by manual or automatic means, control valves, dampers, or other devices requiring up to 1,000 lb. thrust. Bulletin from Detroit Controls, Div. of American Standard.

336 Puverizers. Bulletin from Gruendler Crusher & Pulverizer Co. details the "Super-Master" pulverizer, now available in 24 in. diameter rotor for increased capacity.

337 Pumps, controlled-volume. Bulletin from Milton Roy gives design features and specifications. Built for pressures to 1,900 lb./sq. in.

338 Pumps, liquefied gases. New Folder from Linde Co. (Union Carbide) on performance and specifications of 4 pumps designed specially for liquid oxygen, nitrogen, and argon.

339 Pumps, motor. In sizes from ⅓ to 25 hp., heads to 190 ft., capacities to 775 gal./min. New Bulletin from Ingersoll-Rand.

340 Reactors, glassed-steel. Schematic drawings, installation dimensions, complete material and working specifications for reactors with capacities from 200 to 4,000 gal. Bulletin from Pfaudler.

341 Regulators, gas. New, 36-page Catalog covers Air Reduction Co.'s complete line of cylinder, manifold, and station pressure regulators.

342 Rotameters. Bulletin from Schutte and Koerting describes new line for hazardous and high-pressure fluids at temperatures to 400°F.

344 Separators, entrainment. Metal Textile Corp. offers new Bulletin on technology of mist elimination by wire mesh separators. Data on mesh and grid construction, new vapor velocity graphs.

345 Separators, nozzle-type. Designed and developed for pilot-plant scale, small-production, or laboratory use. Technical data in Bulletin from Centrico.

346 Spectrophotometer. Moderate-priced instrument covers ultraviolet, visible, and near infrared wavelength regions. Brochure from Perkin-Elmer gives operating features, specifications, applications.

347 Thermometers, dial. New, 12-page Catalog from U. S. Gauge Div. of American Machine and Metals, describes theromometers for measurements from minus 40 to plus 1,000°F. Complete selection tables.

348 Thickeners. Bulletin from Eimco, Process Engineers Div., describes process thickeners including hydro separators, reactor-thickeners, air-lift agitators, slurry mixers.

349 Tubing. Brochure from Wolverine Tube, Div. of Calumet & Hecla, titled "The Measure of Tubemanship" describes manufacturing techniques for seamless copper and copper alloy tubing.

350 Tubing, capillary. New, 11-page Bulletin from Superior Tube describes materials, tolerances, finishes, special processing and inspection procedures, methods of flow testing.

351 Tubing, for nuclear applications. Finned and plain tubing for cladding of fuel elements for co-extrusion, heat exchanger tubing, special extruded shapes in rare metals. Wolverine Tube.

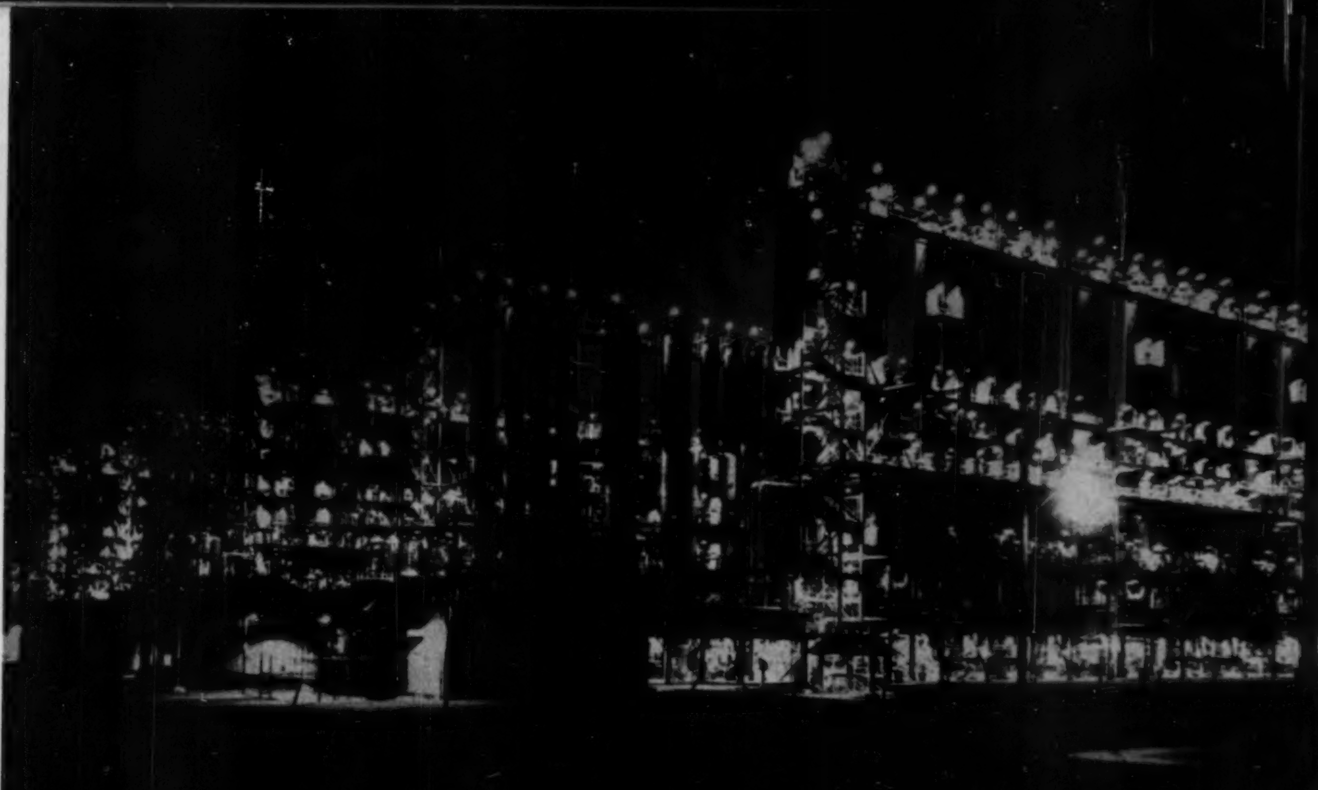
352 Tubing, stainless steel. Folder gives analyses, corrosion and oxidation resistance, temperature characteristics, physical and mechanical properties of 18-8 stainless steels. Babcock & Wilcox.

353 Valves, ball plug. Catalog from Hydril Co. gives full technical details on line of valves with compressible port seal for positive shutoff.

354 Valves, diaphragm. Bulletin from Hills-McCanna gives complete selection data, typical process applications.

A.I.Ch.E. Membership

Brochure—"Know Your Institute"—tells objective aim and benefits to chemical engineers who join this nation-wide organization, includes membership blank. Circle number 604 on Data Post Card.

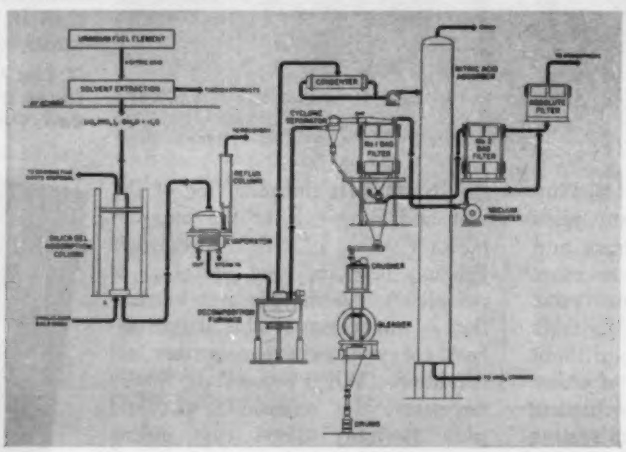


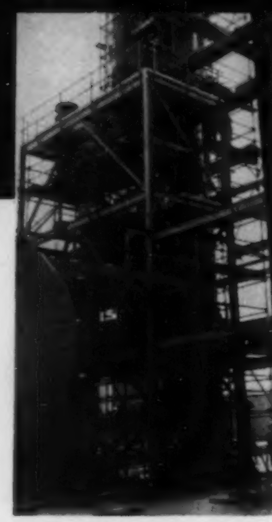
LUMMUS DESIGNS, ENGINEERS, CONSTRUCTS FOR THE NUCLEAR INDUSTRY

Heavy Water Area, Savannah River Plant. Lummus handled design, engineering, procurement and construction liaison of this area.

World-wide designers, engineers and constructors of over 800 major plants for the process industries in the last half century, Lummus now offers its experience for the development of atomic energy installations. Here are some current examples of Lummus work in this field:

Uranium Oxide Recovery Unit of the Savannah River Plant. Lummus handled design, engineering, procurement and construction liaison of this unit.



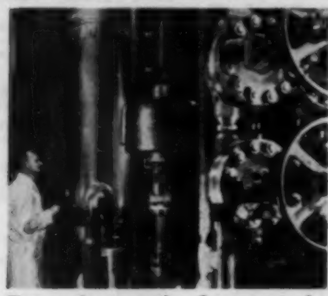


Nitric Acid Recovery Unit of the Savannah River Plant Chemical Separations Plant. Lummus handled design, engineering, procurement and construction liaison of this unit.

Plant engineered and designed by Lummus for Beryllium Corporation to extract beryllium metal from beryl ore.

Ore sintering furnace used to produce beryllium metal.

Below is the high pressure, high temperature test facility, constructed by Lummus at its Engineering Development Center for the Knolls Atomic Power Laboratory. The facility consists essentially of a pressurized water heat exchange system and demineralizing equipment. Reactor fuel and materials samples are inserted in the in-pile test section for study under controlled conditions of temperatures, pressure, radiation flux, and water conditions.

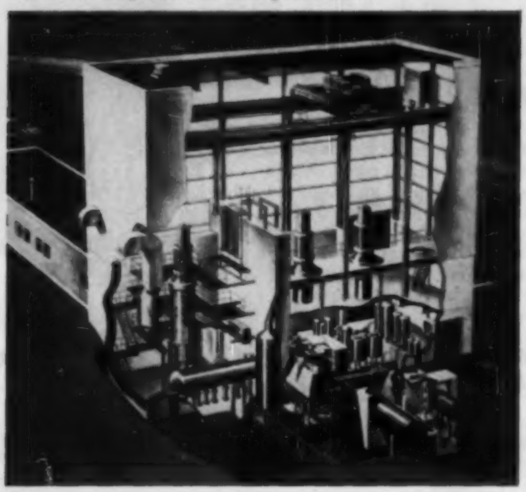


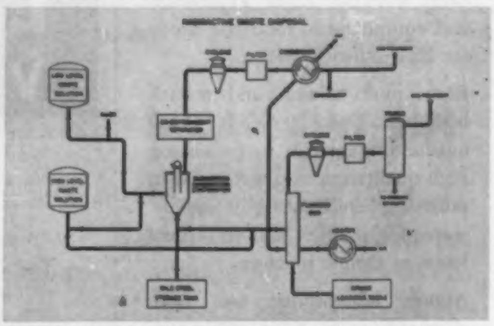
Pressurizer, main flow control valve, loop block valves.

Test Loop Control Panel.

Four loop pump volutes with special cover plates for hydrostatic testing.

This high temperature test facility was designed and engineered by The Lummus Company under sub-contract to Westinghouse Electric Corporation, Bettis Atomic Power Division. Its purpose is to make criticality measurements and to determine flux distributions in water moderated reactors operating at low power levels and elevated temperatures and pressures.





In the not too distant future, large volumes of radio-active wastes will be forthcoming from power reactor operations. Great quantities of this material are now being stored in costly underground tankage. We believe that it would further reactor development to have a more economical and safe waste disposal system to take care of the large radio-active waste volumes. The Lummus approach to this has been directed toward utilizing known engineering techniques which require special consideration due to the unique problems associated with radio-active waste.

Lummus' extensive experience in evaporation, entrainment, condensation, fluidization, material handling and other unit operations, is available to design and engineer radio-active waste disposal systems of the type shown here.

LUMMUS

Visit The Lummus Exhibit, Fifth World Petroleum Congress Exposition, New York Coliseum, June 1-5, 1959.

ENGINEERS AND CONSTRUCTORS FOR INDUSTRY THROUGHOUT THE WORLD
385 MADISON AVENUE, NEW YORK 17, N.Y.

For more information, turn to Data Service card, circle No. 58

NUCLEAR FUTURE

from page 98

Exhibitors at Atom Fair

United States Steel, Pittsburgh, Pa.
Tubing, forgings, structural steels. 141, 138

D. Van Nostrand, Princeton, N. J.
Nuclear reference books. 807

Vard Inc., Pasadena, Calif.
Nuclear control components. 404

Victoreen Inst. Co., Cleveland, Ohio
Reactor control & monitoring. 508, 510

Vitro Corp. of America, New York, N. Y.
Uranium mining, processing, research, engineering, electronics, chemistry. 433

Westinghouse Electric, Pittsburgh, Pa.
Reactor, fuels and equip., electronic tubes. 318, 320, 324

Wolverine Tube, Div. of Calumet & Hecla, Allen Park, Mich.
Copper and aluminum tubing. 111

Hot Laboratories Program

HOT LABORATORIES AND FACILITIES

Georgia Nucl. Aircraft Lab., R. A. Thompson et al., Lockheed, Marietta.
Low Cost Multicurie Radiochem. Facility, A. J. Moses et al., Westinghouse.
Hanford's Radiochemistry Hot Cells, R. W. Dascenzo & K. H. Hammill, GE, Richland.
Intermed. Level Radiochemistry Hot Cell, F. P. Moore, Los Alamos.
Design of Indust. Radioisotope Lab, E. W. Coleman et al., Picker X-Ray Corp.
Design, Constr., & Equip. of New Components Develop. Hot Cell Facilities by Atomics Int., J. M. Davis & B. H. Webb, Atomics Int.
Fuel Element Exam. Facility for Pu Recycle Test Reactor (PRTR), W. S. Kelly, GE, Richland.
Pre-emergency Planning in Radiochemical Facilities, T. W. Hungerford, ORNL.
KAPL Hot Lab Radiation Corrosion Facility, W. F. Niebuhr, Knolls.
Lab for Nuclear Research by a Petroleum Co., J. R. White, Socony Mobil, Paulsboro, N.J.
Low Cost 100-Curie Shield Facility, A. J. Gavin & R. A. Blomgren, Argonne.
Portable Hot Lab, E. Mestre, et al., Comm. l'Energie Atomique, France.
Building a Facility for Handling Kilocurie Amounts of Gamma Emitters, P. Germond, Comm. l'Energie Atomique, France.

GENERAL MANIPULATIVE EQUIPMENT

Brookhaven Rectilinear Manipulator Model 4, L. G. Stang, Jr., Brookhaven.
Design Criteria for Heavy Duty Master-Slave Manipulator, D. G. Jelatis, Cen. Res. Labs., Red Wing, Minn.
Electronic Master-Slave Manipulator ANL Model 3, R. Goertz, Argonne.
Slave Robot Developments, R. Goertz, Argonne.
Mech. Master-Slave Model 9 Manipulator, R. Goertz, Argonne.
French Master Slaves, G. Cherel, Comm. l'Energie Atomique, France.

VIEWING

Equip. for Microscopic Observation of Radioactive Mtls., R. L. Seidenberg, Bausch & Lomb.
Gamma Ray Induced Elec. Discharge in Radiation Shielding Window, V. Culler, Corning Glass.
Remote Viewing Scope for Hot Cells, J. L. Maulbetsch & J. J. Lerse, Lerma Eng. Corp., Northampton, Mass.
Measurements Through Hot Cell Window Using Optical Tooling, A. A. Abbatiello, ORNL.
Effects of Radiation on Surfaces of Shielding Glasses, K. Ferguson, Argonne.
Pre-Lighting Installation, G. Gustevich, Atomics Int.

CELL FIXTURES AND SPECIALIZED MANIPULATIVE EQUIPMENT

Combination Wet Cutoff Wheel and Milling Machine, E. C. Lusk & R. J. Burian, Battelle.
Radioactive Decontamination by Ultrasonics, L. M. Behr & W. L. Bryant, Westinghouse.
Commercial Equip. for Analytical Chemistry by Remote Control, J. J. McCown et al., Argonne.
Creep Test System, R. P. Stearns, Knolls.

continued on page 116

NUCLEAR FUTURE

from page 114

Hot Laboratories Program

Dry Storage Facility for Irradiated Mtls., S. O. Lewis & S. E. Dismuke, ORNL.
Device for Remotely Slitting Aluminum Tubes, P. H. Chismar, Dupont, Savannah River.
Air-Driven Abrasive Cut-off Machine for Remote Operations, P. H. Chismar, Dupont, Savannah River.
Machines & Tools for Underwater Use at West Milton Fuel Service Facility, B. B. Biggs, Knolls.
Storage & Handling Facilities for Large Hospital Radium Unit, N. A. Baily, Roswell Pk. Mem. Inst., Buffalo, N.Y.
Magnetic Couplings for Totally Sealed Systems, A. Oltmann, Brookhaven.
Gamma Scanner for In-Cell Use, D. K. Dieterly et al., Battelle.
Remotely Controlled Drop-Wt. Test Mach. for Brittle Fracture Studies, L. E. Steele & J. R. Hawthorne, U.S. Naval Res. Lab.
Wet Cut-off Saw, R. F. Stearns, Knolls.
Spectrometer Positioning Device, W. A. Pate, ORNL.
Remotely Operated Charpy Test for Brittle Fracture Studies, J. R. Hawthorne & L. E. Steele, U.S. Naval Res. Lab.
Devices for Structural Material Tests, J. L. Bernard et al., Comm. l'Energie Atomique, France.

GAMMA IRRADIATION FACILITIES

90-Curie Co-60 Irradiation Unit, A. L. Riegert & J. W. T. Spinks, Univ. of Saskatchewan.
Technology of Gamma Irradiation with Multikilocurie Co-60 Sources for Scientific, Indust., and Medical Res., P. Joklik, Transcontinental Atomic Co., Lugano, Switz.
Gamma Irradiation Facility Employing 8 Spent MTR Fuel Elements, P. J. Manno, Continental Oil.
10,000 Curie Co-60 Irradiation Cave, A. Danno et al., Japan AE Res. Inst., Tokyo, Japan.
Co-60 Irradiation Facility, R. E. Carson & B. I. Parsons, Dept. of Mines & Tech. Surveys, Ottawa, Canada.
Multipurpose Agricultural Co-60 Gamma Irradiator, H. J. Teas, Univ. of Florida.

OPERATIONS AND TECHNIQUES

Disassembly and Sampling of Irradiated EBWR Fuel Subassembly, C. F. Reinke & L. S. Markheim, Argonne.
Liquid Waste Disposal at Bettis, W. L. Bryant & L. M. Behr, Westinghouse.
Techniques & Equip. used at KAPL Radioactive Mtls. Lab Remote Metallography Cell, B. D. Wemple, Knolls.
Designing Equip. for Underwater Facilities, J. K. Pigenshau & G. C. Kelly, General Mills.
Remote Fabrication of SRE-Type Fuel Rods, T. A. Godking et al., Atomics Int.
In-Pile Testing of Fuel Elements, D. C. Kaulitz, GE, Hanford.
Dynamic Corrosion Facility for Irradiated Fuel, K. R. Hunter, Knolls.
Heat Treating Techniques for Irradiated Fuel Mtls., E. D. Grazzini, Westinghouse.
Radioactive Mtl. Handling, R. R. Pouse & A. L. Maharam, Westinghouse.
Hydrostatic Burst Test on Irradiated Fuel Elements, J. H. Bowling, Westinghouse.
Handling Solid Wastes from Caves at Savannah River, M. R. Caverly, DuPont.
ETR Experiment and Tube Removal, W. F. Nirbuhr, Knolls.
High Level Dissolution and Processing of Field Release Test 1 Samples, L. O. Sullivan, GE, Vallecitos.
Analytical Service for Homogeneous Reactor Test, U. Koskela et al., ORNL.

PROBLEMS IN SIMULTANEOUS HANDLING OF ALPHA — AND GAMMA — EMITTING MATERIALS

Invited Paper, W. H. Langham, Los Alamos.
Radiological Safety Problems Associated with Alpha Emitters, D. D. Meyer, Los Alamos.
Plutonium Handling Hazards, T. S. Chapman, Dow Chemical, Rocky Flats.
Invited Paper, J. R. Lilienthal, Los Alamos.
Alpha—Gamma Metallurgical Res. Facilities, R. Goertz, Argonne.
High-Level, Alpha-Gamma Cell, S. Dismuke, ORNL.
Transfer of Solid Waste Through Alpha and Gamma Barriers, R. A. Blomgren, Argonne.
Invited Paper, L. J. Defferding, GE, Hanford.
De-Canner for EBR-11 Pins, J. Simon, Argonne.

ROUND TABLE DISCUSSION OF OPERATIONAL PROBLEMS

Chairman: R. Westphal, Westinghouse.
Panel Members: L. D. Turner, GE, Hanford; W. B. Doe, Argonne; E. S. Schwartz, Westinghouse; G. J. Deily, Savannah River; D. D. LaRoque, Knolls; R. R. Pouse, Westinghouse.

future meetings

1959—MEETINGS—A.I.Ch.E.

• Atlantic City, N. J. March 15-18, 1959. **A.I.Ch.E. National Meeting.** Chalfonte Haddon Hall Hotel. For details, (see p. 138)

• Chicago, Ill. Mar. 31-Apr. 2, 1959. Hotel Sherman. **21st Amer. Power Conf.** Sponsored by **A.I.Ch.E., 8 other Eng. Soc. & 14 Coll. and Univ.** Write: R. A. Budenholzer, Mech. Eng. Dept., Illinois Inst. Tech., 3300 Federal St., Chicago 16.

• Cleveland, O. April 5-10, 1959. **Nuclear Congress. Co-sponsored by A.I.Ch.E. and others.** A.I.Ch.E. representative: E. B. Gunyou, Alco Prods., Inc., Schenectady 5, N. Y. (see page 86)

• Kansas City, Missouri, May 17-20, 1959. Hotel Muehlebach. **A.I.Ch.E. National Meeting.** Gen. Chmn.: F. C. Fowler, Consulting Chem. Engr., 7515 Troost Ave., Kansas City, Mo. Tech. Prog. Chmn.: Fred Kurata, Chem. Eng. Dept., Univ. of Kansas, Lawrence, Kansas. **Reaction Kinetics** (2 sessions). M. M. Gilkeson, Dept. of Chem. Eng., Tulane Univ., New Orleans, La. **Petrochemicals**—G. E. Montes, Nat'l Petrochemical Corp., Tuscola, Ill. **International Licensing and Collaboration**—R. Landau, Scientific Design Co., 2 Park Ave., New York, N. Y. **General Papers** (3 sessions). J. O. Maloney, Univ. of Kansas, Lawrence, Kan. and Merk Hobson, Univ. of Nebraska, Lincoln, Nebr., G. H. Beyer, U. of Missouri, Columbia, Mo. **Thermodynamics of Jet & Rocket Propulsion**—G. C. Szego, Gen. Elect. Aircraft & Gas Turbine Div., Cinn. 15, Ohio. **Computers and Pipelines**—R. L. McIntire, The Datics Corp., 600 Camp Bowie Blvd., Fort Worth, Texas. **Present Status Liquid Metals Technology**—H. M. Rodekohr, Ethyl Corp., P.O. Box 341, Baton Rouge La. **Ten Ways to Improve Technical Reports**—Robert Gunning, Blacklick, Ohio. **Growth Potential of the Heavy Chemical Industry in the Central U. S.**—N. J. Ehlers, Columbia-Southern Chem. Corp., Pittsburgh 22, Pa. **Special Joint A.I.Ch.E.—AIME Symposium in Petroleum Production Technology: Session 1—Non-Equilibrium Fluid Mechanics**—M. J. Rzasa, Cities Service Res. Lab. Box 402, Cranbury, N. J.; Session 2—**Role of Wetting and Capillarity in Fluid Displacement Processes**—C. S. Kuhn, Magnolia Petroleum Co., 907 Thomasson Drive, Dallas Tex. (see page 146)

• Storrs, Conn. August 9-12, 1959. Univ. of Conn. **A.I.Ch.E.-A.S.M.E. Heat Transfer Conferences.** Prog. Chmn.: M. T. Cichelli, Eng. Research Lab., Dupont, Wilmington, Del.
Final paper deadline, March 15, 1959.

• St. Paul, Minn., Sept. 27-30, 1959. Hotel St. Paul. **A.I.Ch.E. National Meeting.** Gen. Chmn.: W. M. Podas, Asst. Rsch. Dir., Economics Lab., Guardian Bldg., St. Paul, Minn. Tech. Prog. Chmn.: A. J. Madden, Jr., Univ. of Minn. **Mixing**—J. Y. Oldshue, Mixing Equip. Co., Inc. P.O. Box 1370, Rochester 3, N. Y. **Size Reduction**—E. L. Piret, Chem. Eng. Dept., Univ. of Minnesota, Minneapolis 14, Minn. **Missile Construction Materials**—B. M. Landis, Gen. Elect. Co., Cleveland 12, O. **Physical Properties of Liquids**—S. E. Isakoff, Dupont Co., Eng. Dept., Expr. Sta., Wilmington, Del. **Molecular Engineering**—M. Boudart, Princeton U., Chem. Eng. Lab., Princeton, N. J. **Chemical Economics as a Unit Process**—M. H. Baker, 1645 Hennepin Ave., Minneapolis 3, Minn. **More Research for Your Dollars**—T. S. Mertes, Sun Oil Co., 1608 Walnut St., Philadelphia 3, Pa. **Process Control**—I. Lefkowitz, Case Inst. of Techn., Cleveland, Ohio. **Thin Film Techniques Involving Heat and Mass Transfer**—H. J. Karakas, Lincoln Bldg., 60 E. 42 St., N. Y. 17, N. Y. **Chemical Warfare**—Co-Chmn.: L. E. Garono & E. J. Gruen, Army Chem. Corps. Bldg. 250, Baltimore Md. **Safety in Air and Ammonia Plants**—W. A. Mason, Dow Chem. Co., Midland, Mich. **Management of New Product Development**—L. B. Hitchcock, Consultant, 60 East 42 St., New York 17, N. Y. **The Chemical Engineer and Professional Societies**—C. R. Ringham, Phillips Petroleum Co., Bartlesville, Okla.
Deadine for papers: May 27, 1959.

• San Francisco, Calif., December 6-9, 1959. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: Mott Souders, Jr., Shell Development Co., 4560 Horton St., Emeryville 8, Calif. Tech. Prog. Chmn.: C. R. Wilke, Div. of Chem. Eng., Univ. of Calif., Berkeley, Calif. **Process Dynamics**—E. P. Johnson, Dept. of Chem. Eng., Princeton U., Princeton, N. J. **Operations Research**—R. R. Hughes, Shell Dev. Co., Emeryville 8, Cal. **Progress and Problems in Jet and Rocket Combinations**—C. J. Marsel, NYU, University Heights, New York 53, N. Y. **Secondary Oil Recovery Methods**—F. H. Poettman, Ohio Oil

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future meetings

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Co., Littleton, Colo. **Financing in the Chemical Industry—Fundamental Aspects of Chemical Engineering in the Pulp and Paper Industry**—J. L. McCarthy, Dept. Chem. Eng., U. of Washington, Seattle, Wash. **Turbulence and Turbulent Mixing**—T. Baron, Shell Devel. Co., Emeryville, Cal. **Eectro-Chemical Engineering**—C. W. Tobias, Dept. Chem. Eng., U. of Cal., Berkeley, Cal. **Outlook for National Resources**—C. Meyer, U. of Calif., Berkeley, Calif. **Student Program**—D. M. Mason, Stanford U., Stanford, Calif. **General Technical Session**—M. Manders, Union Oil Co., Rodeo, Calif. Deadline for papers: August 6, 1959.

1959—A.I.Ch.E. Local Section One-Day

• Beaumont, Tex., March 13, 1959. **6th Annual Joint Technical Mtg. Sabine Area Section A.I.Ch.E. & Tex.-La. Gulf Section ACS.** Gen. Chmn.: H. Taylor, Jr. Gulf Oil Corp., Port Arthur, Tex. Prog. Chmn.: B. O. Wilkins, Gulf Oil Corp. Two morning sessions on Chemistry and Chem. Eng.; aftn. session on fuels. Chem. session: **The Function and Applic. of Silicon Transistors**—speaker to be named; **Crystallization of Polyethylene**—C. F. Hammer, DuPont; **Application Techniques for Reservoir Evaporation Control**—R. G. Dessler, Consultant, San Antonio, Tex. **Chem. E. session: Design Consid. for Applying Refractories in Hi-Temp. Proc. Equip.**—R. W. Brown, Carborundum Corp.; **Process Scale-Up**—speaker to be named; **Use of Radioactive Tracers in the Chem. Ind.**—L. F. Tischler, Tracerlab, Inc. **Fuels session: Hydrofining for Superior Jet Fuels and Kerosenes**—G. T. Gwin, Humble Oil; **110-Octane Fuel from Commercial HF Alkylation Unit**—E. K. Jones, Universal Oil; **High Energy Aviation Fuels**—R. A. Wells, Gulf R&D; **Anti-Static Agents for Jet Fuels**—R. A. Burdett, Shell Oil.

• Philadelphia, Pa. March 31, 1959. University Museum, 33rd & Spruce Sts., U. of Pa. **7th Annual All-Day Meeting Philadelphia-Wilmington Section A.I.Ch.E. Recent Advances in Chemical Engineering Practice.** Gen. Chmn.: R. Fleming, Sun Oil. Morning session: **Plasma—A High Temperature Heat Source**—M. L. Thorpe, Thermal Dynamics Corp., Hanover, N. H.; **Solids Mixing**—R. H. Jebens, Patterson Fdry. & Mach. Co., East Liverpool, O.; **Biochemical Techniques**—E. L. Gaden, Columbia U.; **Chemical Reactor Design**—D. E. Boynton, Hercules Powder; Afternoon session: **Mini-Plants**—J. A. Knaus, M. W. Kellogg; **Saline Water Techniques**—O. M. Elliott, Sun Oil; **A Material User's View of Trends in Chemical Technology**—A. Pechukas, G.E. Co.

• Pittsburgh, Pa., April 10, 1959. Mellon Institute, 4400 Fifth Ave., Pitts. Seminartype **Catalysis Symposium. Joint One-Day Regional Meeting: Akron, Central Ohio, Cleveland, Detroit, Ohio Valley, Philadelphia, Wilmington, Pittsburgh, Toledo, National Capital and Northern W. Virginia Sections A.I.Ch.E.** Gen. Chmn.: C. Halloway, Gulf R&D. Prog. Chmn.: R. Beckman, Carnegie Tech. **Morning session: Catalyst Development Procedures**—R. C. Davidson & J. F. Kucirka, Harshaw Chem. Co.; **Role of Fundamental Catalyst Rsch. Prog. in Petroleum Rfng**—J. A. Anderson et al, Humble Oil; **Semi-Automatic Reactor for Catalytic Rsch**—W. K. Hall et al, Mellon Inst.; **Devel., Desgn, & Constr. of Catalyst Testing Units**—E. Chererson & J. Donovan, Artisan Ind. **Aftnoon session (2): Gas Distrib. Studies in Fluidized Catalytic Oxidation Units**—J. E. Longfield, Cyanamid; **Anal. of Kinetics of Catalytic Proc. of Residual Stocks**—B. J. Lerner, Gulf R&D; **Fundamental Kinetics Appl. to the Reverse Shift Catal.**—T. E. Corrigan, O. Mathieson. **Polymerization of Olefins w/ Hetero. Organo-metallic Catal.**—A. E. Jeltch, Koppers; **Catal. Hydration of Olefins**—R. Odioso et al. Gulf R&D; **Kinetics of Liq.—Phase Hydrogen. of Cyclohexene**—L. B. Bitar & R. Price, U. of Cinn.

1959—Non-A.I.Ch.E.

• New York, Feb. 23-26, 1959. Commodore Hotel. **44th Ann. Mtg. TAPPI.** . . . Chicago, Mar. 16-20, 1959. **Natl. Assoc. Corros. Eng.** corrision show. . . . Baton Rouge, La. Mar. 18-20, 1959. At L.S.U. **22nd Ann. Short Course for Supts. & Ops. of Water & Sewerage Systems.** . . . Norman, Okla. Mar 23-24, 1959. Campus of U. of Oklahoma, 2nd. **Conf. on Theory of Fluid Flow through Porous Media.** . . . Wilmington, Calif. Mar. 26-27.

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Thermal stress analysis of refinery piping systems

GORDON N. SMITH, *Fluor Corp.*

One of the many problems in the engineering of a refinery is the design of the piping system connecting the various pieces of equipment. The piping system is installed at ambient temperatures and may be operated at elevated temperatures of 1,000°F or higher. Since the pipe line expands more than 9 inches per 100 feet at these temperatures, large destructive forces can be exerted on the equipment which restricts this expansion, and excessive stress concentrations can occur in the piping system.

The piping designer lays out a piping system, based on his intuition and experience, to provide for maximum flexibility. The piping system is then analyzed to obtain the forces and moments on the anchors and the stresses throughout the system, in order to ensure that these are less than the allowable. A complete, rigorous, flexibility analysis of a fairly typical 3-anchor, 3-dimensional piping system can occupy an experienced analyst 3 weeks or more. Since production schedules make a rigorous analysis impractical, short-cut methods with many simplifying assumptions are used. To compensate for the errors introduced by these assumptions, the piping system is generally over-designed. This increased flexibility is obtained by introducing superfluous U-bends, elbows, and expansion joints into the system. With the large diameter high-grade alloy piping currently being used in many installations, the addition of this unnecessary piping can become quite expensive. Thus, the importance of an accurate flexibility analysis, with the feasibility of computing various alternative configurations in order to optimize the system, cannot be overemphasized.

In a rigorous analysis of a piping system, the piping is allowed to expand without restraint, and the forces and moments required to return the piping system to a configuration compatible with its restraints are calculated. These calculations are extremely tedious, requiring the computation of as many as 18 moments and products of inertia terms for each pipe section, and the solution of 6 simultaneous equations for each branch in the system. A digital computer solution provides the only feasible means of obtaining accurate analysis at low cost and high speed.

The computer program to solve the pipe stress problem is a rigorous solution, using matrix algebra as in the Brock Matrix Method (*1*). The flexibility (deflection per unit force) for every section, straight run, or elbow in a branch is obtained as a 6×6 matrix. The superposition of the matrices for all the sections in the branch gives the overall flexibility coefficients necessary for the solution of the 6 simultaneous equations. These coefficients are calculated in turn for each branch, and the system of simultaneous equation thus obtained is solved to give the resulting forces and moments at the anchors. These forces and moments are then transferred to the desired points in the piping system and the stresses computed.

The computer used at Fluor is of medium speed with a 4,080 word drum memory. The program is stored on the drum and the data read in on paper tape. Pipe sections for each branch are read in and operated on sequentially; thus there are no restrictions as to the number of pipe sections per branch. All calculations are carried out to eight significant digits to insure accuracy of computation. The program checks all input data for dimensional consistency and will reject the problem if the data fail this consistency check. It will also pin-point the pipe section where the consistency check failed, thus indicating where in the data sheet the

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PIPE STRESS DATA SHEET

GENERAL DATA				LINE TEMPERATURE			MEAN COEFF. OF EXP.			ALLOWABLE STRESSES			[illegible]
0	1	2	3	4	5	6	7	8	9	10	11	12	13
CONT. NO.	LINE NO.	A	H	T_1	T_2	T_3	α_1	α_2	α_3	S_1	S_2	S_3	T_o
				°F	°F	°F	°F^{-1} x 10^6	°F^{-1} x 10^6	°F^{-1} x 10^6	PSI	PSI	PSI	°F

	ANCHOR DATA						COLD SPRING DATA			
0	1	2	3	4	5	6	7	8	9	10
A	X	Y	Z	ΔX	ΔY	ΔZ	Ec	Eh	Sh	f
	FT.	FT.	FT.	IN.	IN.	IN.	PSI x 10^6	PSI x 10^6	PSI	[illegible]
1										
2										
3										

SECTION DATA					BEND DATA				PHYSICAL PROP.				non stand.		SKEWED	
0		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
BR	SECT	R or L	Xf	Yf	Zf	Xb	Yb	Zb	θ	μ	Ec	O.D.	t	k	i	γ	AXIS
*		FT.	FT.	FT.	FT.	FT.	FT.	FT.	DEG.		PSI x 10^{-6}	IN.	IN.			DEG.	

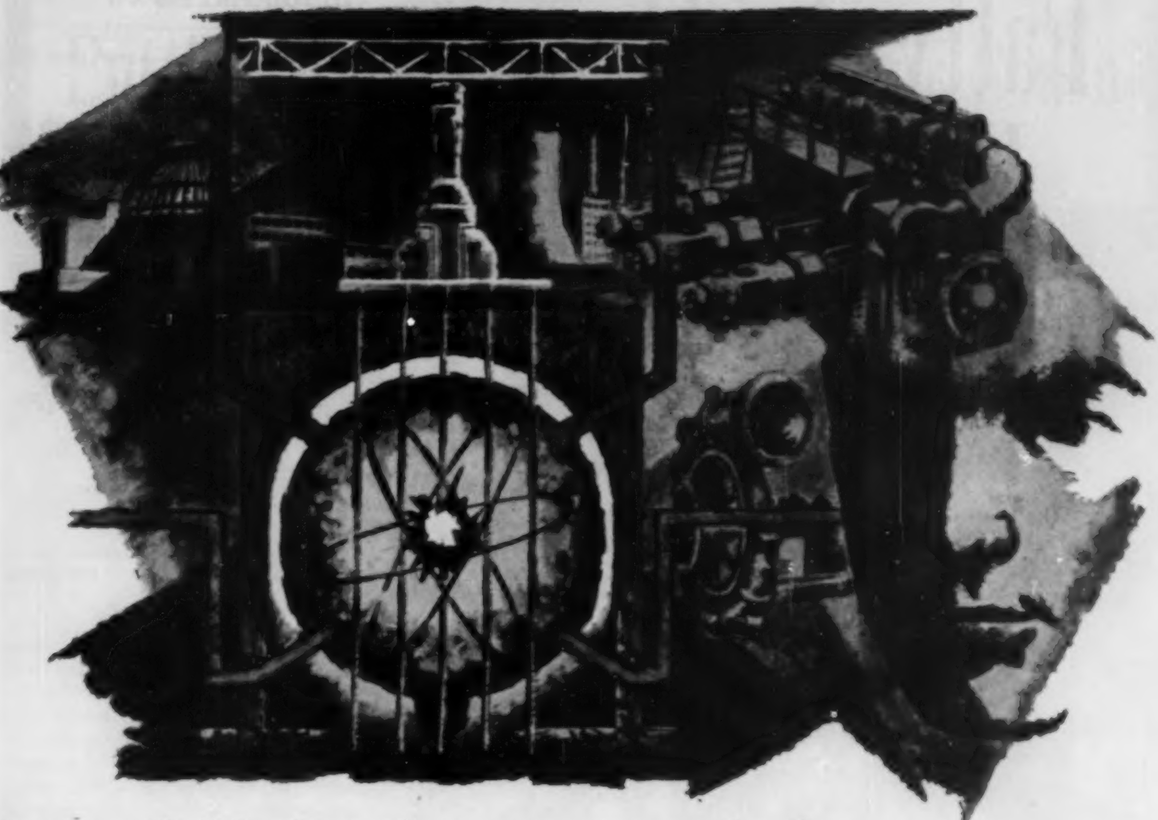
Figure 2. The pipe stress data sheet has been simplified to require only the minimum of data needed to do the job.

PIPE STRESS CALCULATIONS

SECTION	M (b) Ft. Lbs.	M (t) Ft. Lbs.	S (b) PSI	S (t) PSI	S (E) PSI	S (A) PSI	EX. ALL.
1.01	4682	- 21	+ 2136	- 4	+ 2136	+ 29100	
1.021	4537	- 21	+ 6098	- 4	+ 6098	+ 29100	
1.02m	3395	+ 3263	+ 4564	+ 744	+ 4801	+ 29100	
3.05m	1962	+ 2643	+ 3294	+ 909	+ 3763	+ 23300	
3.05f	2886	+ 1078	+ 4844	+ 371	+ 4900	+ 23300	
3.07	2460	- 3533	+ 1693	- 1215	+ 2963	+ 23300	

ANCHOR	F (x) Lbs.	F (y) Lbs.	F (z) Lbs.	M (x) Ft. Lbs.	M (y) Ft. Lbs.	M (z) Ft. Lbs.	
1	- 183	+ 42	- 184	- 480	- 6045	- 1964	R (H)
	+	-	+	+	+	+	R (C)
2	+ 385	- 273	- 152	- 2696	+ 142	- 4437	R (H)
	-	+	+	+	-	+	R (C)
3	- 202	+ 230	+ 336	+ 3343	+ 1525	+ 1759	R (H)
	+	-	-	-	-	-	R (C)

Figure 3. The output consists of the stresses at various points throughout the system and the reaction anchors.



For more information, turn to Data Service card, circle No. 29

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data were filled out incorrectly.

The piping engineer starts with an isometric sketch of the piping system (Figure 1). He then fills out a data sheet (Figure 2) which has been simplified to require only the minimum of data, the coordinates of the system, the physical properties of the

PIPING SKETCH

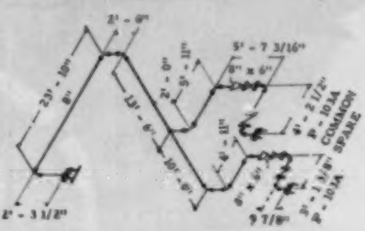

Figure 1. The piping engineer starts with an isometric sketch of the piping system.

piping, and the operating conditions. The time required to fill out and check a data sheet is approximately one hour; to punch and verify data for the computer approximately one-half hour; computer time approximately ten minutes for a fairly complex 3-anchor problem, four minutes for a 2-anchor problem. The output (Figure 3) consists of the stresses at various points throughout the system and the reactions at the anchors. Using simplified methods, the design engineer would take 3 to 4 days to compute a complex 3-anchor problem, and would not have as complete an analysis as shown here, nor the confidence in the accuracy of his results.

It has been the experience at Fluor that manpower costs for an approximate solution run about four times the cost of a rigorous computer solution. This is on a straight cost per hour basis and does not take into account peak load periods when skilled manpower would not be available to eliminate bottlenecks. Actual savings in material costs on recent projects have been extremely gratifying. On one recent piping system it was possible to save $10,000 by eliminating a U-bend and going to less expensive alloy piping as a result of a rigorous computer solution. On another system it was possible to eliminate over $8,000 worth of expansion joints which would have been included as a result of an approximate analysis.

(1) Brock, J. E., "A Matrix Method for Flexibility Analysis of Piping Systems", Journal of Applied Mechanics, Dec., 1952.

future meetings

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1959. Los Angeles Harbor Jr. College. **8th Ann. Instrumentation Short Course.** . . . Philadelphia, Apr. 20-21, 1959. Bellevue-Stratford Hotel. **3rd Natl. Conf. on Analog & Digital Instrumentation.** . . . Ann Arbor, Mich. June 15-24, 1959. **Intensive Course in Automatic Control.** U. of Mich., Coll. of Eng. Registration closing date, Apr. 15.

1960—MEETINGS—A.I.Ch.E.

• Atlanta, Ga. Feb. 21-24, 1960. **A.I.Ch.E. National Meeting.** Gen. Chmn.: J. W. Mason. Dean, Coll. of Eng., Georgia Tech. Tech. Prog. Chmn.: F. Bellinger, Georgia Tech., 225 North Avenue N. W., Atlanta 13, Ga. **Kinetics**—C. D. Holland, Chem. Eng. Dept., Texas A&M, College Sta., Texas. **Pesticides**—D. J. Porter, Diamond Alkali, Box 348, Painesville, Ohio. **Nuclear Engineering; Petroleum, Turpentine, and Solvents; Rubber and Plastics Applied to Textile Fibers; Bioengineering-Radioisotopes; Pulp and Paper; Engineering Sales; Rockets and Missiles; Management of Small Plants; Engineering Education; Mineral Engineering; Fundamentals.**

• Mexico City, Mexico, June 20-24, 1960. **A.I.Ch.E. National Meeting.** Tech. Prog. Chmn.: G. E. Montes, Nat'l Petrochemical Corp., P.O. Box 100, Tuscola, Ill. **Chemical Engineering in Latin America**—John Mayurnik, Grace Chem. Co., 3 Hanover Square, New York 4, N. Y. **Petroleum Production; Minerals and Metals; Biochemicals and Foods; Equipment.**

• Tulsa, Okla., Sept. 4-7, 1960. **A.I.Ch.E. National Meeting.** Gen. Chmn.: E. W. Kilgren, P.O. Box 591, Tulsa, Okla. Tech. Prog. Chmn.: K. H. Hachmuth, Phillips Petroleum Co., Bartlesville, Okla. **Foams—Their Use and Control**—C. S. Grove, Jr., Syracuse U., Collendale, Syracuse 10, N. Y. and R. L. Tuve, U. S. Naval Resch. Lab., Washington 25, D.C.

• Washington, D. C., Dec 4-7, 1960. **A.I.Ch.E. Annual Meeting.** Gen. Chmn.: J. L. Gillman, Jr., 1700 K St. N.W., Wash. 6, D.C. Tech. Prog. Chmn.: D. O. Myatt, Atlantic Research Corp., Alexandria, Va.

1960—Non-A.I.Ch.E.

• Moscow, USSR, June 1960. 1st Congress of International Fed., Automatic Control. To cover areas of **Theory, Hardware, & Applications of automatic control.** U.S. participation sponsored by American Automatic Control Council. Affiliated societies: **A.I.Ch.E., ASME, AIEE, IRE, ISA.** A.I.Ch.E. Chmn.: D. M. Boyd, Universal Oil Prods., Des Plaines, Ill. Abstracts of papers by March 1, 1959; completed papers by July 15, 1959.

Unscheduled Symposia

Correspondence on proposed papers is invited. Address communications to the Program Chairman listed with each symposium below.
Computers in Optimum Design of Process Equipment: Chen-Jung Huang, Dept. of Chem. Eng., Univ. of Houston, Cullen Blvd., Houston 4, Texas.
Preparation of Catalytic Cracking Charge Stocks and Quality Criteria Therefore: Wheaton W. Kraft, Lummus Co., 385 Madison Ave., New York 17, N. Y.
Solar Energy Research: J. A. Duffie, Director of Solar Energy Laboratory, Univ. of Wisconsin, Madison, Wis.
Hydrometallurgy—Chemistry of Solvent Extraction: G. H. Beyer, Dept. of Chem. Eng., Univ. Mo., Columbia, Mo.
Process Dynamics as They Affect Automatic Control—D. M. Boyd, Universal Oil Prods., Des Plaines, Ill.

A $740,000 prime instrumentation contract for the nuclear portion of the new Enrico Fermi Atomic Power Plant, now under construction near Detroit, has been awarded to Bailey Meter Co. of Cleveland. Both pneumatic and electronic control systems will be used; transistorized components will be employed in all electronic systems.

nuclear news

Nuclear Engineering Division elects officers

At the recent Annual Meeting of the A.I.Ch.E. Nuclear Engineering Division, held at the National Annual Meeting in Cincinnati, the new slate of officers of the division for 1959 was introduced by chairman-elect J. W. Clegg. Those who will serve for the coming year are: Chairman, J. W. Clegg; vice-chairman, W. Rodger; secretary-treasurer, C. E. Dryden; executive committee, O. L. Dwyer and R. W. Moulton.

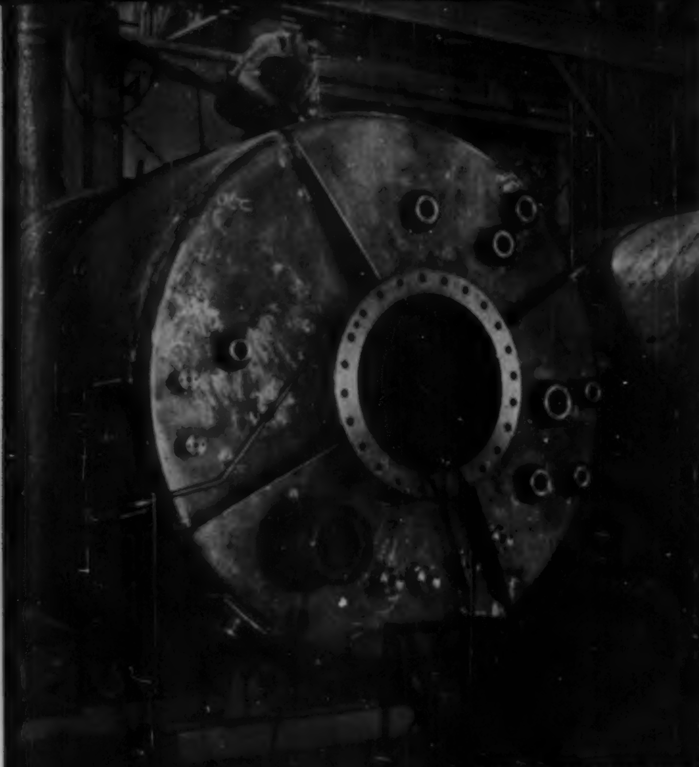
The privately-owned nuclear fuels business of Mallinckrodt Chemical Works has been turned over to a newly-formed company, Mallinckrodt Nuclear Corp. The new subsidiary will take over all facilities and personnel of the Mallinckrodt Special Metals Division, including a $2 million nuclear fuel production center at Hematite, 45 miles south of St. Louis.

The United Kingdom Atomic Energy Authority, England, has purchased a Model 231R "PACE" analog computer from Electronic Associates, Long Branch, N. J.

Standard fuel elements for nuclear reactors are now available from Sylvania-Corning Nuclear. First to hit the market will be four standard types for use in low-power reactors, other types will follow as developed. Earlier step by Sylcor to lower nuclear fuel cycle charges was announcement in February, 1958, of a "package fuel plan" which established a fixed price as a single and total charge to the customer for delivery of completed elements.

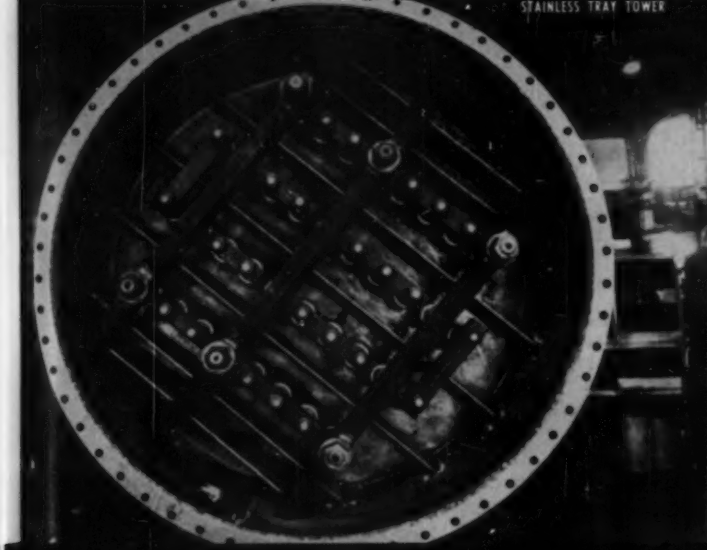
Nuclear research in South Korea receives a helping hand with announcement of a $350,000 U. S. Government contribution toward the cost of a multi-purpose 100-kilowatt solid homogeneous TRIGA Mark 11 to be built by General Atomic for installation near Seoul for the Korean Atomic Energy Research Institute.

Base charges at which U-233 and plutonium will be made available for research and development to private individuals and companies in the U. S. and to foreign governments under agreements for cooperation have been set by AEC. The charges are $15 per gram of U-233 and $12 per gram of plutonium.



STAINLESS WASTE TRANSFER TANKS

REACTOR CONTAINMENT HOUSING



STAINLESS TRAY TOWER

JIG FIELD WASTE TANKS

The use of outside engineering agencies

Nevin K. Hiester

Chemical Engineering Section
Stanford Research Institute
Menlo Park, California

Generally, there are three major types of outside services available—consultants, engineering firms, and research organizations. Consultants are usually very highly qualified and specialized individuals, or a group of individuals, used for assistance or trouble shooting in their specific fields of competence. Normally, they do not provide research facilities, other than routine testing or analysis, but instead depend on their very specific stock of knowledge and experience for the problem at hand.

Engineering firms are often specialized with respect to the industries they serve and to certain classes of unit processes and unit operations. Even the larger companies, which provide a broad range of engineering services, usually have several areas of special proficiency. As a general rule, the client furnishes the engineering company with basic design information about a new process and sets at least the product and raw material specifications. Some engineering firms license process patents. The engineering services range from preparation of initial flow sheets, through detailed plant design, to construction and start-up of the plant.

Contract research organizations provide essentially the same services as the research department of a chemical company itself. That is, they undertake problem-solving and the development of new processes and process equipment, following them up to bench scale, or in some cases to the pilot plant phase. They can obtain the process data needed by the engineering firms for their plant designs, and they use consultants themselves to supplement their own areas of competence.

There are a number of types of research organizations, other than those associated with chemical companies themselves. These include government laboratories, independent commercial laboratories, independent not-for-profit institutes, and universities. Only a few government laboratories are available for research on problems of the process industries. One such institution is the Forest Products Laboratory, at Madison, Wisconsin, which does enter into cooperative agreements for research services if the work is consistent with existing programs. Most universities, proper, eschew applied research; some have established affiliated organizations for this purpose. Universities and government laboratories usually reserve the right to publish research findings.

The independent commercial laboratories, and the independent not-for-profit institutes, are distinguished from each other by specializing in different areas of competency. For instance, among other things, A. D. Little is well known for its work in cryogenics, and Foster D. Snell for its work in detergents. Among other specialties, Battelle is known for its activities in metallurgy, and Armour for its work in ceramics.

Non-Profit research Institutes

Private, nonprofit research institutes are relatively new tools of scientific research. The major institutes and the years they started research activities are:

1.	Mellon	1913
2.	Battelle	1929
3.	Armour	1936
4.	Southern	1944
5.	Midwest	1944
6.	Cornell Aeronautical	1946
7.	Franklin	1946
8.	Stanford	1946
9.	Southwest	1947

The acceptance and utilization of these institutes by industry and government has skyrocketed. The research volume for the nine major not-for-profit institutes mentioned above was:

1930	\$560,000
1940	11,600,000
1950	24,000,000
1955	60,000,000
1956	80,000,000
1957	100,000,000

On the average, this research is divided about 25% in engineering, 28% in chemistry, 25% in physics, and 22% in other fields of research. It is about ⅔ government-sponsored and about ⅓ sponsored by industry or the research institute itself.

There are a number of reasons why a chemical company uses such independent institutes.

1. To obtain special skills and facilities. A research institute provides a very large pool of talent and equipment. Many specialists are available in many different fields and can be called on for any research project. This permits the client company to supplement its staff with specialized talents for a set of problems for which it is not economic to hire a full-time staff member for the client's own research department. Likewise, there are many cases where the company has a very specialized, one-time research problem, perhaps quite different from those normally studied in the research department. It is considerably cheaper for them to utilize an outside research organization already staffed with specialists and provided with the specialized equipment required.

2. For the placement of overflow work. The client's staff in the research department may be overburdened with problems and unable to solve them within the time schedule desired. The overload may then be contracted to the independent laboratories. Along the same line, in cases of emergency and with such outside facilities available, it may be advantageous to reduce lead time by utilizing the outside research organization during the time that the staff and facilities of the company's research department are being built up to handle the overload.

3. To obtain a fresh approach. The research institute's staff can be assigned to one project only and thus devote full time to it, away from the day-by-day pressure of current problems that often keep the company research scientists and engineers from uninterrupted and creative thought. Similarly, the assignment of the problem away from internal company influences will permit its review by research scientists and engineers who can be objective and not hindered by preconceived notions of how the problem should be attacked, because "this is the way all problems of this sort have always been attacked by the company." Again, a research scientist, not prejudiced by having worked with the problem for many years, may look at it more dispassionately.

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Outside agencies

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4. For research of interest to more than one company. A large number of problems are brought to research institutes because they are of concern to a group of companies or to the entire industry and, therefore, are supported in an independent research organization so that the results will be available to all. Alternatively the research problem may be too large for support by one company, and a combine is then formed solely for sponsoring the research.

Argument against

There are also arguments for not using independent institutes. There are companies which are not normally eager to permit proprietary company information and data to be taken outside of the company, or they may want the research experience gained on the problem to remain in the research department staff. One method of solving these problems is a provision by the research institute that the nature of the information obtained be kept classified within the project team. The pool of research know-how gained during the project is returned to the client as part of the final technical report.

Another problem is that of control of the technical program and of the financial expenditures by the client company. Normally, research organizations attempt to solve this problem by directing the research through a steering committee consisting of representatives of both the client and the institute. During the steering committee meetings, whether they be in person or by phone or mail, information as to the status of a research program, with respect to the research milestones and the financial expenditure curve, is provided to the client so that control can be maintained of project costs and accomplishments.

Another problem is that of communication, that is, keeping the client informed of what is happening and of pertinent, valuable results. Geographical distance is often quoted as adding to the problems of communications. This, of course, is not so true in today's era of rapid air transportation and relatively efficient and economical phone communication. Again, however, the problem can be solved by frequent progress reports and steering committee meetings.

The initiation and operation of a research project generally proceeds

continued on page 136

LOOKING FOR MORE HEAT

FROM THE FUEL YOU'RE NOW USING?

AN AIR PREHEATER CAN PUT AN EXTRA 1000° INTO YOUR FURNACE

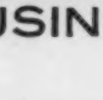
You can get more heat — from the same amounts of your regular fuel — with a Ljungstrom® Air Preheater. An Air Preheater can recover as much as 1000°F from the exhaust of stills or boilers and return it to the combustion air of any kind of fuel-burning equipment. Extra furnace efficiency will in turn permit use of advanced boiler designs, finer controls and a more uniform, more profitable product.

You save fuel with preheated air, too. Even if you recover only 45°F from stack gas, you'll save 1% of your fuel bill. Recover 1000°F, and you can maintain present operating temperatures *on 20% less fuel.*

There's also less maintenance on a Ljungstrom-equipped furnace. Fuel burns more completely in preheated air, so there's less slag, fewer deposits, higher availability of equipment. What you save on maintenance and fuel alone will pay for your Air Preheater in two years or less. "Write-off" can be cut to *as little as nine months* if you use the extra capacity of a preheated furnace to boost product quality.

Free facts on fuel savings

One company's fuel savings with an Air Preheater are factually described in an article by Oliver F. Campbell. Write today for your free copy.



THE AIR PREHEATER CORPORATION

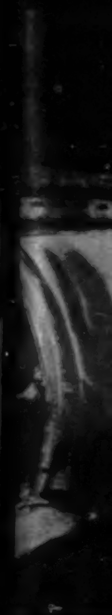
60 East 42nd Street, New York 17, N. Y.

For more information, turn to Data Service card, circle No. 9

Twin Coach Aircraft Division controls this metal bonding autoclave entirely automatically. Quick Opening Doors speed operation.

Hercules Powder uses an acid resistant, forced circulation evaporator to concentrate highly corrosive protein solution.

Fish Products utilizes two evaporators to recover vitamins and protein solids from fish oil waste.



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BLA

Outside agencies

from page 132

through the following steps:

1. Make sure you want research, not just consulting, trouble shooting, or testing.
2. Find a research institute competent in the type of problem you are concerned with. Talk to appropriate staff members and make sure they can handle it. You will definitely be advised if they feel that they are not competent to undertake the program.
3. Request, examine, and, if satisfactory, accept their research proposal.
4. Appoint a member of your staff as technical liaison man and as your representative on the steering committee.
5. Receive progress reports and final reports.

Combustion Engineering, Inc. has filed a registration statement with the SEC for the acquisition of General Nuclear Corp. through an exchange of stock. General Nuclear will be operated as a subsidiary, says Combustion Engineering.

COOPER ALLOY VALVE BRIEFS

THE VALVE AND FITTINGS ANSWER CORNER

Carl Tylka, Cooper Alloy Technical Service Director, answers your questions on stainless valves and fittings.

Q. *How can one remedy a hydraulic hammer produced in a piping system during closing of a motor-operated gate valve?*

A. Hydraulic hammer indicates an excessive pressure buildup rate caused by too rapid a valve closing cycle. Lengthening the time of closure will eliminate this condition.

Q. *What to do about interruption of closure of motor-operated gate valve caused by the torque switch cutting out when in the near-closed position?*

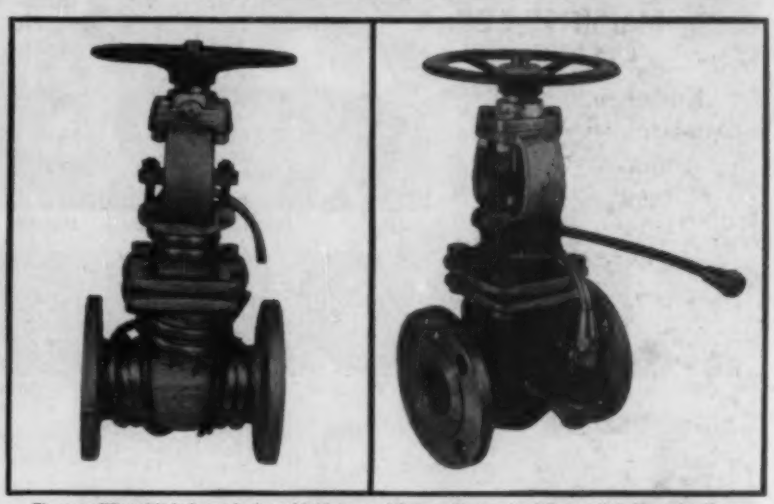
A. Increase the spring load in the operator torque cutout. Obviously, the disc when approaching the closed position develops across it larger pressure drops and resulting friction, which requires operating power in excess of the maximum passable through the torque cutout.

Q. *Does V2B stainless alloy lend itself to use in valve discs?*

A. Yes. V2B's corrosion and erosion resistance, plus its non-galling characteristics, are ideally suited for valve disc applications. Typical Brinell hardness values range from 302, as cast, to 363 when annealed and hardened. V2B contains Mo, Si, Cu, and Be, and is easily machined in the quench-annealed condition (Brinell 269). Corrosion resistance to H_2SO_4, HCl, H_3PO_4, and their salts in the hardened condition exceeds that of all other precipitation-hardenable alloys, and even 316-type stainless. Its resistance to highly concentrated hot HNO_3, however, is less than that of 304 and 316.

Q. *In open-shut operations, which type gate valve is preferable: wedge type, or parallel-faced disc type?*

A. This depends on many variables such as system pressure, temperature, and differential pressure across the disc. With low system pressures and temperatures, the wedge type is preferred for positive shutoff. With high temperature-pressure systems, however, since shutoff tightness is directly affected by pressure drop across the disc, the parallel-faced disc type is preferable, especially in regard to required stem torque and disc binding.



Thermon fills voids between body and tubing, providing continuous heat-flow path between heating element and valve body. It can be easily removed for repair of leakage in tracers

We've Cut Jacketed Valve Cost By 75%

Standard Cooper Alloy stainless steel valve models with low-cost Thermon* jacket are designed for use in hot or cold service

Thermon, a non-metallic plastic compound with highly efficient heat-transfer properties when factory-applied to standard Cooper Alloy stainless steel valves with conventional steam traced or thermal electric systems, permits all the performance advantages and none of the problems generally associated with jacketed units. You can even use standard piping without juggling sizes, and product contamination, usually a big problem with most jacketed units, is not possible, because we have eliminated the need for complicated castings which are subject to hidden defects.

What's more, the costs are one-quarter of what you would expect to pay for jacketed valves. Thoroughly tested under all operating conditions, Cooper Alloy Thermonized valves have the high performance characteristics equal to the most efficient jacketed units, in operating temperature ranges from below zero up to 750°F.

Cooper Alloy Thermonized valves make maintenance problems easy. Should tracer leaks develop, they can be quickly found and repaired. With a minimum of down time required, your processing operation can be continued without a great loss of productive hours and manpower.

With Cooper Alloy Thermonized valves you get all the high quality features you expect in a Cooper Alloy product. You get high-performance, lower-cost jacketed valves, and you can get practically off-the-shelf delivery to meet your production needs. For further details, request engineering data folder from Coope. Alloy Corp., Hillside, N. J.

*Thermon is a product of the Thermon Mfg. Co., Houston, Texas.

For more information, turn to Data Service card, circle No. 23

ATLANTIC CITY

LEWIS C. MARINO, *Benzol Products Co.*

last minute highlights

March 15-18th

Arrangements are complete for the upcoming Atlantic City Resort Meeting. Speakers for the principal events have been announced, the plant trips set, the ladies' program finalized, extra-curricular activities scheduled.

Lunch on Monday will be distinguished by the presence as guest speaker of Alan H. Shapley of the National Bureau of Standards, who was U.S. vice-chairman for the International Geophysical Year. James Creese, president of Drexel Institute will be the speaker at the Tuesday night Banquet.

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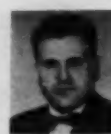
Know your authors for the four-day meeting

Sunday Afternoon

Szego Dixon Ritchey Mettler Ehricke

Monday Morning



Cziner

Sanborn Wessel Sweeney Williams Gigliotti Adams Gabel Lee Hawke Dietz

Treybal Vermeulen Jacques Myers Kendall Schotte

Monday Afternoon

Copulsky Berger Johnson

Magee Atkinson Trice Gustison Karr Hoelscher Thatcher Garrett

Tuesday Morning

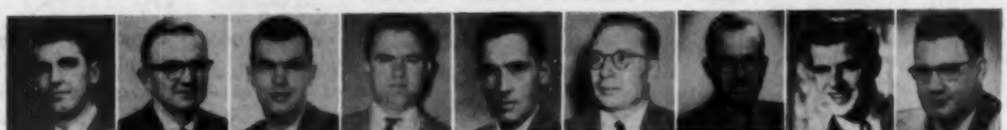
Karp

Archer Doud Webster Stevens Amos Prausnitz Salmon Teller Gordon Vilbrandt

Snow

Tuesday Afternoon

Happel Watson Hart Thomas Keyes Torpey Leone Kern



Lindstedt Corrigan Skelton Jackson Kittredge Donath Mason Petersen Madonna

Wednesday Morning

Blomfield Wellford Wright Pontius Barnett Tomkowit McKibbins Hill Ackerman Longmire

Atlantic City

from page 138

The ladies committee, headed by Mrs. F. J. Van Antwerpen, has arranged a full and diverse schedule of optional events, including trips to the Renault Winery, near Atlantic City, the Fischer Greenhouse, and the Lenox China Showcase. Bowling, boating, bridge, and horseback riding, are also expected to attract a numerous feminine contingent.

Program changes

• Technical Session 14, Tuesday morning, will be called *Thermodynamics of Phase Equilibria* instead of *Thermodynamics of Solutions*. Papers remain unchanged.

• Technical Session 14, *Business and Technology*, will be on Tuesday morning instead of Tuesday afternoon. The fourth paper in this symposium, by D. B. Keyes, will be titled *Evaluating the Evaluators* instead of *Intangibles of Technical Economics* as advertised.

• Technical Session 18, *Care and Feeding of Executives*, has been changed to Tuesday afternoon from Wednesday morning. Papers are unchanged.

• The discussion, *Russian Technical Literature in Chemical Engineering*, moderated by H. E. Hoelscher, will be held Monday night, 8:00-9:30 P.M., instead of Monday afternoon.

Engineering work is well advanced on a "sizeable" phenol plant and formaldehyde unit at the Port Moody, B.C., plant of Reichhold Chemicals (Canada) Ltd, and on another phthalic anhydride plant at the company's St. Therese, Quebec, facilities.

Exchange of patents and knowhow on rubber chemicals has been agreed upon between Naugatuck Chemical (U.S. Rubber) and Farbenfabriken Bayer, A.G. of West Germany.

Vinyl acetate polymerization production will be expanded by 50% at the Meredosia, Ill., plant of National Starch Products. Constructor for the additional facilities will be Blaw-Knox, startup is slated for March of this year.

A contract for engineering, procurement, and construction of a solvent deasphalting plant has been awarded to Badger Manufacturing by the Lion Oil Division, Monsanto Chemical, El Dorado, Ark.

For more information, turn to Data Service card, circle No. 20

Rocket fuels, population effects, at Local Sections

All rocket fuels, either liquid or solid, consist of the fuel itself, and an oxidizer. Fuels can be classified as dipropellants—in which the fuel and oxidizer are stored separately, or mono-propellants — where they are premixed. The main advantage of solid propellants, explained Nevin K. Hiester of Stanford Research Institute to the **Northern California section** *(Wm. B. Hauserman)* in September, is that they do not require the amount of hardware necessary for the handling of liquid propellants. (Hardware refers to the rocket hull, pumps, tubing, and so forth, used to contain the currently-used liquid fuels.)

Although there has been a recent trend back to liquid fuels—mostly as mono-propellants, about a year ago there was a great rush on solid propellants coincident with the launching of Sputnik I and the first Vanguard failure. Many small manufacturers of solid propellants got almost daily offers to merge, usually with larger chemical companies. Since then, the trend has been for larger propellant manufacturers to buy up the smaller companies supplying them with raw materials, until now most of the government contracts are held by five large companies: Aerojet, Thiokol, Astrodyne, Grand Central Rocket, and Hercules.

If the exhaust velocity of a rocket can be increased, its effectiveness (payload, or range) can be increased. This exhaust velocity is the rate of generation of gases resulting from an exothermic chemical reaction. This rate can be increased by increasing the burning surface (in the case of solid propellants), the reaction temperature, and by decreasing the molecular weight (hence increasing the volume) of the reaction products.

Other propellant possibilities now under consideration include nuclear and plasma propulsion. In the former, a working fluid, such as water, is heated to extremely high tempera-

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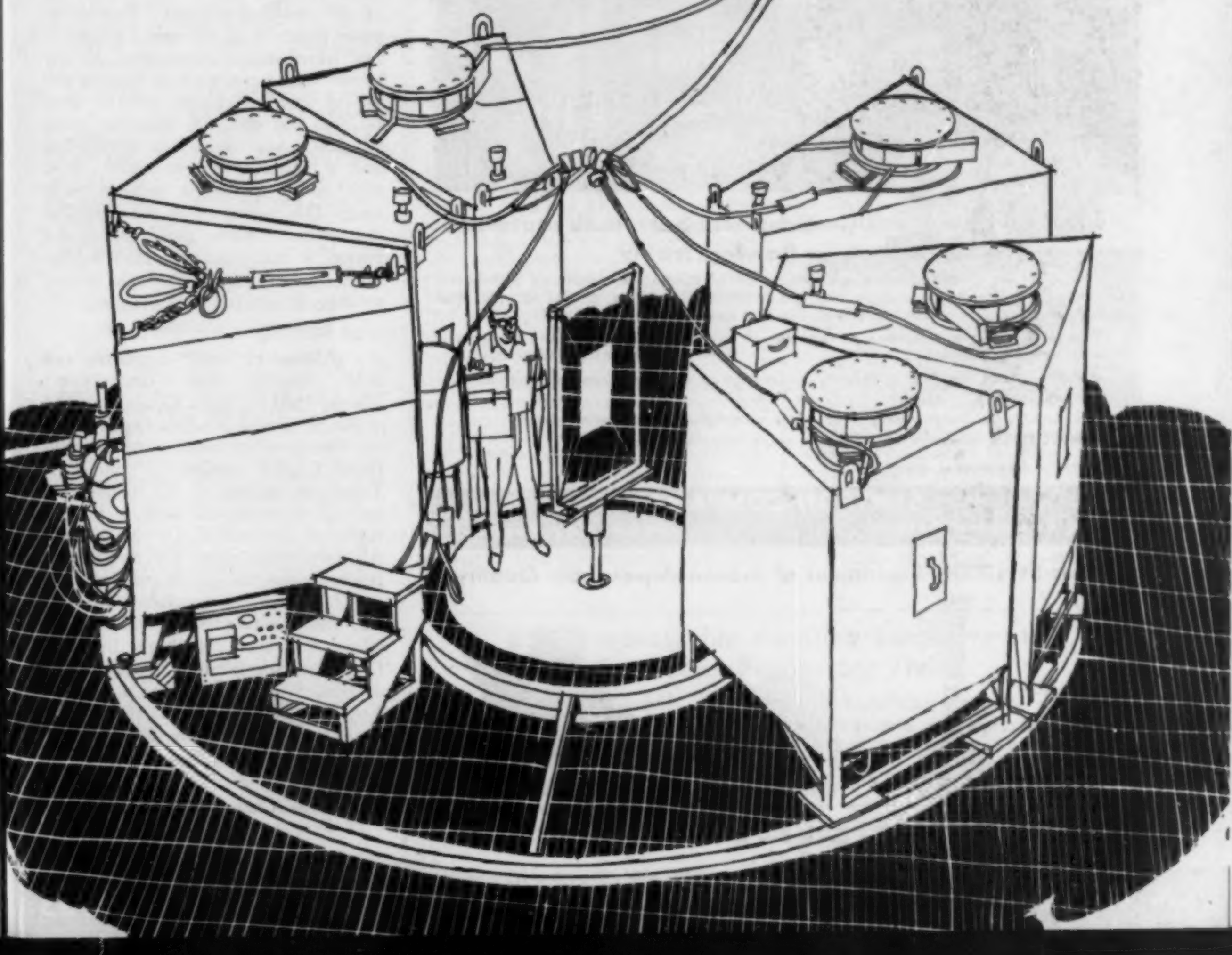


from page 142

tures by nuclear fission, the exhaust providing the thrust; in the latter, thrust is provided by a discharge of arc plasma, or highly ionized substance at tremendous temperatures. This produces very great thrust per mass of fuel, but requires a huge source of electric power to ionize the substance (and to form a magnetic field to contain it out of contact with the walls of the enclosing chamber).

The effect of population changes on economic growth over the next ten years concerned speaker Russell Knoblauch of Minneapolis-Honeywell at the October meeting of the **Maryland Section** *(Philip Messina)*. "It is estimated," said Knoblauch, "that our population will be about 190-million by 1965. But of this number there will be a large decrease in the 25-44 age group, the most productive age group. Thus there will be less active workers than could be expected from the population increase. Compared to this, the gross national product is estimated at $560 billion by 1965. The natural result of this, according to Knoblauch, is that automation will be a necessity in the future to maintain increased production with less labor.

Although the chemical industry has been progressive and dynamic in the application of instrumentation, Knoblauch sees certain pitfalls still to be overcome. It is not wise to employ full scale automation unless system planning is available. Thus, many processes which have been worked out satisfactorily on a manual basis may not in themselves convert easily to automatic instrumentation unless the entire operation is revised. There may even be some processes which can never be economically instrumented, and each individual operation must be examined separately.

Knoblauch estimated that 25% of all instruments sold in this country go to the chemical industry. They comprise about 5% of the new equipment cost for chemical expansions. An example of the potential savings in the use of instrumentation can be seen by the fact that an operator costs $21,000 a year on a four shift basis, and a comparable instrument would save about $7,000 a year in most cases. This means a pay-out period of 2-4 years. Unless such a pay-out period is indicated, Knoblauch cautions against using automatic instruments.

Also meeting

. . . How chemical engineers can help (furnish their brainpower) was outlined by Major General Stubbs of the Chemical Warfare Service during the October meeting of the **National Capital section**. . . .the **East Tennessee section** *(J. C. Umberger)* led off their season with a Ladies' night in September. . . . and plant trips were the order for the **Boston Ichthyologists** *(Ralph Wentworth)*: to Air Force Cambridge Research Center; the **Western New York section** *(Reed E. Garver)*: to Lapp Insulator Company; the **Western Massachusetts section** *(R. A. Coffey)*: to Combustion Engineering's Nuclear Division; and the **Charleston section** *(Dan G. Hulett)*: to the Truax-Traer coal mining operation.

For more information, circle No. ➤ 35

ECO ENGINEERING NEWS

the big name in small pumps for the process industries

Pumping Notes

Centrifugal Designed as Basic Unit in Multi-plant Standardization Program

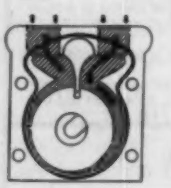
ECO's CENTRI-CHEM* was designed to include all the most desirable operating and maintenance features in a centrifugal pump for general chemical service—and mass-produced at a price, making it profitable for any processing plant to standardize upon it. Type 20 Stainless Steel was selected for the ultimate in corrosion resistance and strength. The mechanical seal is chemically inert, non-contaminating TEFLON†, ceramic or carbon. A removable face plate gives access to all internal parts without disturbing piping. Available, motor or pedestal mounted. Capacity to 40 gpm, heads to 50 ft. Priced as low as $184.00 less motor.

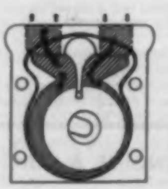
Purifying Uranium

ECO's GEARCHEM* Pumps, providing constant-flow metering with reproducible accuracy within plus or minus one per cent, are employed in a new system for purifying crude Uranium. Several units are already in use here and abroad. These Hastelloy* C pumps, with glass-filled TEFLON gears and bearings, meter exact amounts and concentrations of Hydrochloric and Uranyl Chloride at different points in the system, with accuracy essential to its successful operation.

Pumping Shear-Sensitive Fluids and Missile Grade Propellants

For pumping without mechanically disrupting fluid balance—ECO's ALL-CHEM* rotary displacement pump with its non-shearing, smooth, positive thrust of two axially opposed oscillating impellers producing two overlapping discharge and suction strokes per revolution, provides an almost pulseless flow essential to safe pumping of such media as hydrogen peroxide, hydrazine, nitroglycerine, etc. Also, in handling such fluids as missile grade propellants, subject to internal spark and explosive wave propagation, these pumps are widely preferred, since their self-lubricating TEFLON impellers and bearings eliminate internal spark hazard.

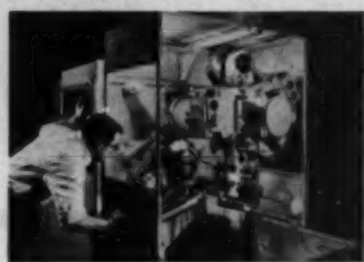




The Responsibility of Leadership

How ECO Builds Better Chemical Pumps at Lower Costs

Eco Engineering Company's position of leadership in the small chemical pump field is primarily the result of advanced engineering and an open mind to the new and improved materials of construction which have revolutionized design possibilities and service expectations. In this connection Eco has pooled the vast materials engineering research of such companies as du Pont, International Nickel, Carpenter Steel, Union Carbide, U. S. Graphite, Carborundum and other outstanding suppliers with their own broad pump manufacturing and application experience to produce their unique and diversified line of rotary, gear and centrifugal pumps for corrosive service.



Automatic "Program" Machining

But building better chemical pumps was not sufficient. Eco insisted their line be lower in first cost as well as in upkeep than pumps of comparable quality. Mass production on the most modern automatic "program" machine tools, where multiple operations are performed to reduce needless labor and handling, was their answer to this requirement.

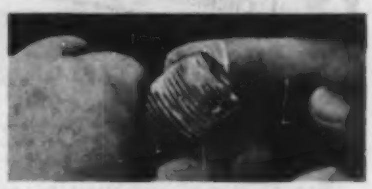
Standardization and Interchangeability

All Eco pumps were designed for precision manufacture with standardization of every component part for interchangeability in original assembly or replacement in the field. Interchangeability of parts and mass production has had another important value to the user. It has permitted manufacture and stocking of a highly flexible inventory to provide immediate delivery of any "specification pump" in the Eco line, as well as a variety of specification variations to meet individual customer needs.

Factory Mutual Approved Chemical Faucet

This Eco Stainless Steel Chemical Faucet is the ultimate for safely dispensing flammable and corrosive fluids. It is the only fume-tight, spring-loaded faucet with TEFLON seals which overcome seizure problems. Ideal for drum dispensing or for standard piping systems. Illustration shows solvent storage area at Eastman Kodak, Rochester plant, where more than 200 Eco Faucets are in use.

TEFLON T-Film* Hydraulic Sealant



Eco's chemically-inert thread sealant and anti-seize compound for metal, plastic, carbon and ceramic systems and equipment was produced originally as an aid to Eco pump users in the nuclear and corrosive chemical fields. After four years of highly successful use, T-Film is now in general use throughout the process industries wherever corrosives are encountered.

ECO Products for Handling Corrosive and Hazardous Processing Fluids

ALL-CHEM Rotary Pumps	CENTRI-CHEM Centrifugal Pumps
MINILAB Rotary Pumps	PUMPMOBILE Portable Pumping Units
GEARCHEM Gear Pumps	CHEMICAL FAUCETS Factory Mutual Approved

Ask for literature on any or all of these ECO Products

*ECO Trademarks. †du Pont Trademark. *Union Carbide Trademark.

ECO ENGINEERING COMPANY · 12 New York Avenue · NEWARK 1, N.J.

. . . Steak, jazz and engineering at KANSAS CITY meeting . . .

JAMES DELURY, *J. F. Pritchard & Co.*

"The Heart of America" will play host to the A.I.Ch.E. at its May 17-20 National Meeting at Kansas City. It is no accident that Kansas City is the hub of a thriving, dynamic segment of America's chemical industry. Here are the natural resources—oil, minerals, grains, lumber. Here is the geographical center of the continent (except for Alaska), served by twelve trunkline railroads and eight airlines.

Older industrial residents of the Kansas City industrial community are typified by Spencer Chemical at Pittsburg, Kansas, Corn Products Refining in North Kansas City and Standard Oil, Phillips Petroleum, Colgate-Palmolive, Procter & Gamble, Thompson-Hayward Chemical. Newcomers which illustrate the growing pattern of chemical diversification are such firms as Callery Chemical, whose high energy fuels plant is now on stream at Lawrence, Kansas, and the new Du Pont cellophane plant west of Lawrence.

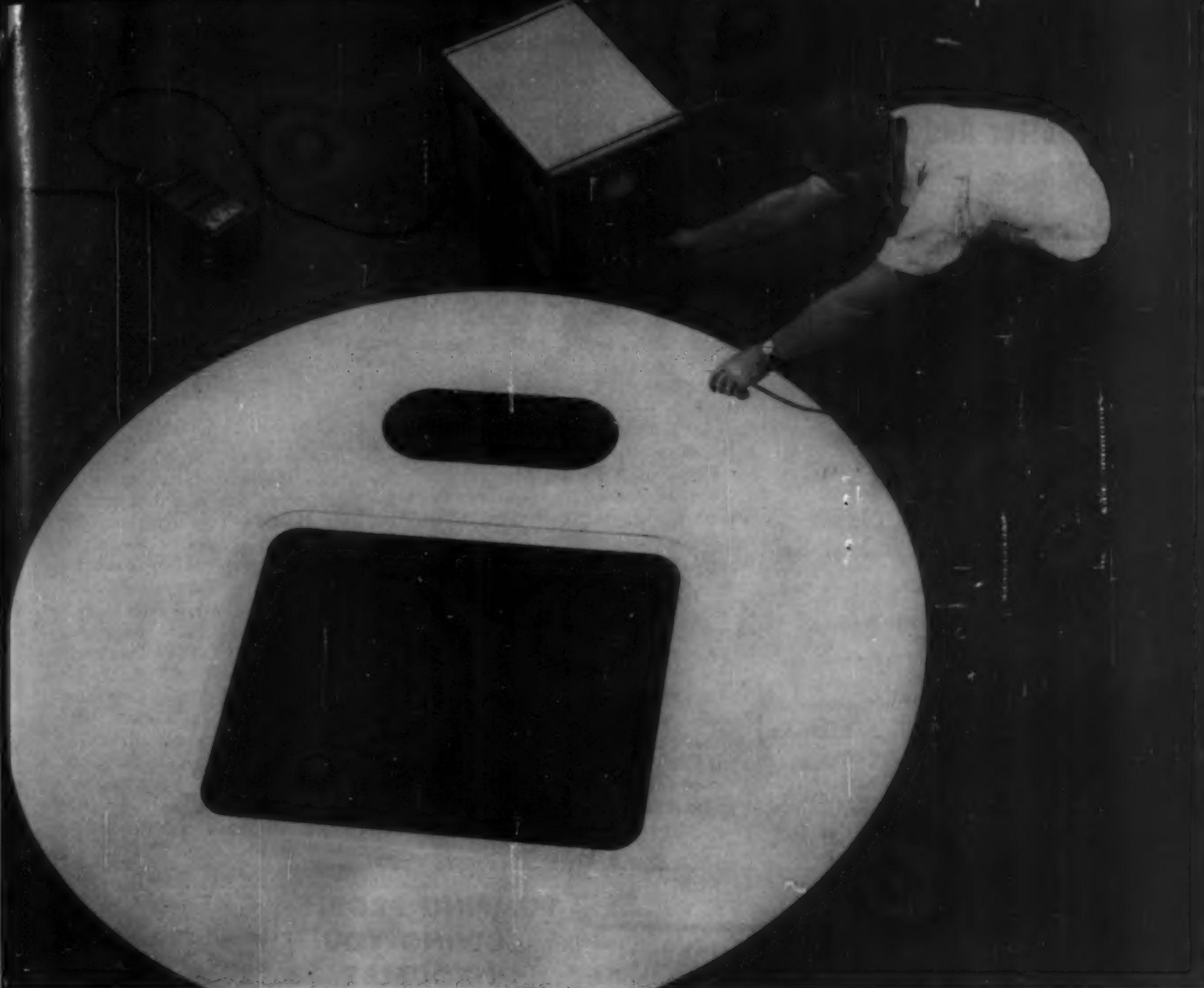
The design and construction fraternity is also well represented by such firms as J. F. Pritchard and C. W. Nofsinger, and the equipment fabrication field by such nationally-known companies as Black, Sivalls & Bryson. Chemical engineering visitors to Kansas City in May will have an opportunity to inspect many of these plants at first hand as part of the extensive plant tour schedule for which arrangements are already almost complete.

Unity in the engineering profession will be the guiding theme of a special panel discussion slated to ring up the curtain on Sunday afternoon. Taking part will be representatives of several of the great national engineering societies. Fireworks from the floor can be counted on to enliven this controversial session.

Unit operations

An A.I.Ch.E. tradition seems to have sprung into existence almost overnight. The Unit Operations Luncheon, inaugurated with such resounding success at the Annual Meeting in Cincinnati, will be the event of the day on Monday at Kansas City. Judging from the "standing-room-only" stampede at Cincinnati, it is recommended that reservations be made as early as possible (space is necessarily limited at each of the tables). Details

continued on page 148



Kansas City Meeting

continued from page 146

will be published by CEP as soon as received. It will be remembered that at these luncheons each table is devoted to one of the Unit Operations, with the free discussion being led by a recognized authority in the field.

Information never before made public is promised for the symposium on International Licensing and Collaboration, to be led by Ralph Landau of Scientific Design. In these hectic days of currency devaluations, the European Common Market, and of increasing scientific ties between American and foreign chemical industry, the questions at stake here have become the business of almost every chemical engineer.

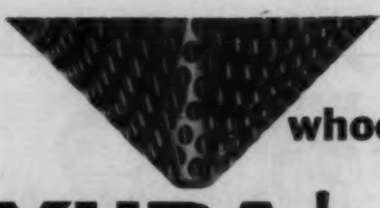
G. C. Szego of General Electric will head up another session which should be of extraordinary interest—Thermodynamics of Jet & Rocket Propulsion. The technical program proper will be rounded out with a variety of symposia cutting clear across the chemical engineering field—Reaction Kinetics, Equilibrium Mechanics, Petrochemicals, to name only a few. Complete program details will be published in next month's *CEP* (March).

Extra-curricular activities at the Kansas City meeting will get off to a flying start with the traditional Get-Acquainted Party on Sunday evening, will wind up with the Banquet on Tuesday night at which the guest speaker will be Chancellor F. D. Murphy of the University of Kansas. The ladies, of course, will not be neglected—a full program is being planned for their distraction and their pleasure.

Way out

Jazz (Kansas City style) is one of the town's claims to fame—many of the jazz "greats" got their start here in the 20's and 30's. Top-flight jazz still echoes through certain of the night spots. For those who lean toward the legitimate theatre, the Victoria and the Municipal Auditorium offer Broadway hits; for the serious musicians, there is the Kansas City Philharmonic at the Music Hall.

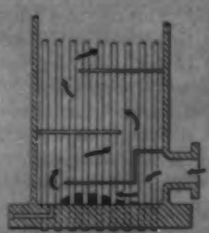
A second pillar of Kansas City fame is the time-honored "Kansas City sirloin steak." Visitors are advised to sink their teeth into at least one specimen. This, of course, is not the only thing to eat in Kansas City—fine restaurants are many and various.



whoever heard of a conical tube sheet?

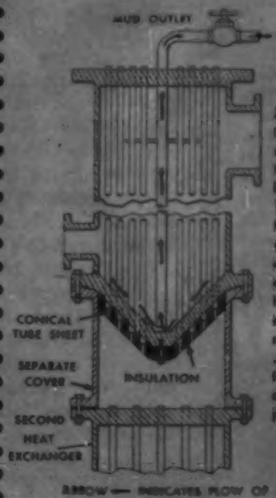
YUBA! and helped solve ARAMCO'S problem

THE PROBLEM



In the original heat exchanger, shown at left, sludge in the cooling water settled on the flat tube sheet, causing corrosion at the tube joints. A stepped baffle to increase water velocity across the tube sheet and a connection to blow away the sludge helped only partially. Within one year some tubes failed because of the sludge-induced corrosion.

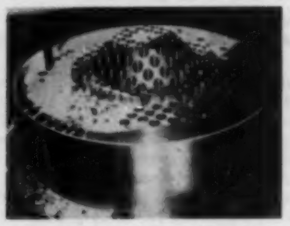
THE SOLUTION



Aramco believed that a conical tube sheet would permit the sludge to settle to the apex of the cone, where it could be blown from the exchanger. Yuba's experience quickly solved the fabrication details. Because of abrasive particles in the fluid coming from the bottom heat exchanger, ferrules were placed in the tubes and erosion-resistant insulation around the ferrules to protect the tube ends . . . the whole job, an illustration of Yuba cooperation with client engineers to reach a practical solution of a problem.

PRODUCING THE CONICAL TUBE SHEET—THE INGENIOUS PART OF THIS YUBA HEAT EXCHANGER

A forged tube sheet conical both inside and out could not have been drilled because there would have been no purchase for the drill. So Yuba started with a forging which was flat outside and conical inside and then drilled holes on the flat outside surface.



The outside conical surface takes shape as unwanted metal is cut away. When the previously drilled holes become shallow, the drill was reinserted and the holes made deeper. Then more metal was cut away. This process was repeated until . . .

. . . the conical tube sheet was finished. The tube sheet was placed in the Yuba heat exchanger, tubes inserted and welded to sheet. Then replaceable ferrules and insulation were used to protect the tube ends from erosion . . . truly an engineered heat exchanger.

YUBA CONSOLIDATED INDUSTRIES, INC.

Heat Exchangers designed and manufactured East and West

YUBA HEAT TRANSFER DIVISION Honesdale, Pa.
ADSCO DIVISION Buffalo, N. Y.
YUBA MANUFACTURING DIVISION Benicia, Calif.

Towers | Expansion Joints | Pressure Vessels | Structural Steel

For more information, turn to Data Service card, circle No. 99

W. K. Davis talks on Energy Engineering

Plants being built today to use conventional fuels may well have a problem in obtaining the desired form of fuel at reasonable prices toward the end of their useful lives, stated W. Kenneth Davis, in the A.I.Ch.E. Professional Progress Award Lecture delivered at the recent Cincinnati Annual Meeting. The energy situation in the U.S. will become grave long before reserves are actually exhausted, continued Davis, with costs of exploring and developing the remaining reserves increasing hyperbolically and having to be charged largely against current production costs.

While there is no immediate prospect of serious overall shortages of conventional fuels in the U.S., "there is a serious problem in the distribution of energy resources with respect to requirements and the transport of energy to relieve these imbalances," went on Davis. In the past, most of our great industrial and population centers grew up near cheap and abundant sources of fuel and other raw materials. Now, we are finding that the energy resources of these centers are either being exhausted, or that the rate of production from them cannot be expanded to meet increasing demands. Areas like California and Florida are finding it necessary to import ever-increasing quantities of fuel and are becoming almost entirely dependent on the transport of various forms of energy over large distances, and at very considerable and increasing cost.

Davis went on to consider various ways of meeting the energy crisis.

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Nuclear power, he said, seems destined to fill a real need in this rapidly changing picture. It would, he pointed out, require only about one freight car of today's "standard" nuclear fuel elements every three weeks to transport as much energy as that provided by a 300,000 B/D oil pipeline operated continuously.

However, there are difficulties. The most troublesome characteristic of nuclear reactions is the radioactivity associated with them. Most serious problem is gamma rays, which can only be shielded by heavy masses of material. No trick is known, said Davis, to make lighter or more compact shields, although they seem to be "invented" and announced every month or two.

Going on to consider possible applications of nuclear energy, Davis thinks that the use of nuclear energy for small engines for propulsion—autos, trucks, small planes—is highly unlikely, as is its use for railroad propulsion. This opinion is based chiefly on factors of weight and cost. Nuclear power may be feasible fot large aircraft, he considers, although

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the safety problems are most difficult to deal with, and may prevent any large scale use in this connection. Unmanned space rockets, on the other hand, pose an absolute necessity for nuclear power.

Vast amounts of heat are, of course, used in manufacturing processes. In some cases, the amounts needed for a plant or a unit are sufficiently large so that nuclear heat is likely to be useful and economic. However, Davis points out, in many cases, the amounts of energy needed in one place are so small, or the form in which the energy is needed is so specialized, that there is little prospect of utilizing nuclear energy. "This is not to imply," says Davis, "that there will not be substantial and profitable uses of nuclear power for process energy—there will be, but the studies which have been made do not lead to a belief that the proportion of use will be very high in the foreseeable future."

Looking even further into the future, Davis emphasizes that the accomplishment of a true controlled thermonuclear reaction will be only the beginning, not the end, of the research and development needed to achieve usable and practical power-producing machines. It is likely, he continues, that controlled thermonuclear reaction will have many of the limiting characteristics of fission reaction. Such units seem certain to be large, not only in physical size, but in output. Such a machine seems likely to be much less portable than a fission reactor. There will be problems of radioactivity, also, though perhaps not to the same degree as with fission reaction. In fact, the neutrons emitted will lead to some special shielding problems. "Will controlled thermonuclear reactors solve the problems of small and portable energy sources? The answer that it is most unlikely that they will," concluded Davis.

Herbert Hoover, Jr. has been elected a member of the board of directors of Monsanto Chemical Co. Hoover, a consulting engineer, served as Under Secretary of State from 1954 to 1957.

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Full-size production machines, automatic recorders, feature this pulverizer testing lab at Stedman Foundry & Machine. Hammer mills, impactors, cage disintegrators, aid in determination of correct horsepower, speeds, capacities.

One-third of a gram of polonium-210 furnishes the radiation which is converted into five watts of electricity in a radio-isotope generator (SNAP) developed by the Nuclear Division of the Martin Co. Photo above shows the "spoke" arrangement of thermoelectric elements around the core, photo at left gives an idea of the size of the device which weighs only five pounds. This is a "proof of principle" device, says AEC.

Claimed to be largest high-corrosive resistant glassed-steel reactor ever built, this giant is 120 in. O.D., 166 in. high. Fabricator was Pfaudler.

Art and functional requirements have been combined in the design of this modernistic refinery control center at La Gloria Oil and Gas, Tyler, Texas. The unit is a circular, air-conditioned building with double glass insulating walls. Design by Blaw-Knox.

NUCLEAR DEVELOPMENTS

Inside this 87-ft. aluminum dome (above, left) is what is said to be the world's largest privately-owned research reactor. The 5-million-watt reactor of Industrial Reactor Labs in Plainsboro, N.J. (Above) The "swimming pool" of the Industrial Reactor Labs reactor. Participants in IRL are: American Machine & Foundry; American Tobacco; Atlas Powder; Continental Can; Corning Glass; National Distillers; National Lead; Radio Corp. of America, Socony Mobil Oil; and U.S. Rubber. Cost of the project—about $4.5 million.

Carrier Corp. officers inspect model of a salt water conversion pilot plant to be built by their company for the U.S. Interior Department. The plant will use a "freezing-out" process, will turn out 15,000 gallons per day of fresh water. Fabrication of parts is under way, ground has been broken.

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Robert M. Aude becomes vice-president and general manager of the Heyden Chemical Division of Heyden Newport Chemical Corp. Aude joined the corporation in 1953, was successively manager of the Fords and Garfield, N. J. plants. In 1956, he became director of sales planning and coordination.

Edward W. Comings, (left) head of the school of chemical and metallurgical engineering at Purdue University since 1951, has been appointed dean of the school of engineering at the University of Delaware. Comings succeeds **William W. Hagerty,** who left the University of Delaware last August to accept the deanship of the school of engineering at the University of Texas.

Francis W. Winn, formerly technical director of Fractionation Research, Inc., has joined Fritz W. Glitsch & Sons, Inc., as director of research and development for fractionation trays. Prior to his work with Fractionation Research, Winn had been associated with Pan-American Petroleum Corp., Socony-Mobil Oil Co., and Catalytic Construction.

Frank W. Bowen has been appointed assistant to the vice-president in charge of manufacturing for Sun Oil Co. He succeeds **W. Henry Linton,** who retires after 40 years of service with the company.

A. L. Antonio, who directed Aerojet-General's solid propellant research and development between 1944 and 1954, has returned to Aerojet-General as vice-president, Chemical Division. For the past 4 years, Antonio has been general manager of the Chemical Division of The General Tire & Rubber Co.

American Smelting and Refining has elected **Edward M. Tittmann** vice-president and director. In addition to his new duties, Tittmann will continue to act as chairman of the board and chief executive officer of Southern Peru Copper Corp., in which Asarco holds a majority interest. Tittmann joiner Asarco in 1929 as a chemist in the laboratory of the Garfield, Utah, copper smelter.

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Frederick M. Belmore, who has headed the Special Metals Division of Mallinckrodt Chemical since its formation, will be vice-president, director, and general manager of Mallinckrodt Nuclear Corp., newly-formed subsidiary which will take over all of the company's nuclear fuels business. Prior to his association with Mallinckrodt, which he joined in 1955, Belmore was assistant to the board chairman of Singmaster & Bryer, New York.

New president of Firestone Synthetic Rubber & Latex Co. is **J. C. Roberts.** Roberts is a member of the Rubber Advisory Committee of the General Services Administration, and has served as a delegate of the U.S. Department of State to International Rubber Study Group Conferences since the group was formed in 1945. A member of Firestone's first college training class in 1924, Roberts has been engaged for more than 30 years in the buying and marketing of rubber.

Lauchlin M. Currie has resigned as a vice-president of Union Carbide Nuclear Co. to become vice-president of Babcock & Wilcox Co., where he will be in charge of the Atomic Energy Division. Currie's association with the American atomic energy program began in 1943 when he was selected as Associate Director of War Research for the Manhattan District atom bomb project.

William H. McCoy has been named managing director of Du Pont (United Kingdom) Ltd., succeeding **David H. Conklin** who has been appointed to the new position of European director of Du Pont's International Department, London.

Dewey and Almy Chemical Division, W. R. Grace, has named **Ralph L. Wentworth** as manager of its Shoe Products Research Department. Wentworth succeeds **Cary S. Giles,** who has resigned to take a position with Plastic Coating, Inc., Holyoke, Mass.

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Datics Corp. has elected **Robert L. McIntire** as director, and **Cloyd M. Roberts** as vice-president. McIntire, with Datics for 2½ years, has specialized in scientific computing since 1953.

New appointments at Allied Chemical's Central Research Laboratory, Morristown, N. J. include: **George Joris** as manager of research; **Donald A. Rogers** as manager of project analysis; and **Frank Porter** as assistant to the director of research and development.

Robert W. Schramm has joined Southern Nitrogen Co. in the new position of general manager of development. Schramm, who came to Southern Nitrogen from Union Carbide Development Co., will be concerned with long-term corporate planning and evaluation of new business opportunities.

American Potash & Chemical has named **David R. Stern** as manager of research at its Los Angeles plant.

Nelson J. Donahue becomes chief of the Reactor Materials Branch, Technical and Production Division, Savannah River Operations Office, AEC. Donahue succeeds **Paul J. Hagelston,** now deputy director, Technical and Production Division. Prior to joining AEC in 1952, Donahue was with Titanium Alloy Manufacturing Div., National Lead Co., Niagara Falls, N. Y.

Administrative changes at A. E. Staley Manufacturing Co., following the retirement of **R. E. Greenfield,** vice-president for manufacturing, include: appointment of **William B. Bishop, Sr.** as general superintendent; naming of **G. James Dustin** as technical superintendent; and appointment of **W. Robert Schwandt** as methods and materials superintendent, succeeding Dustin.

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COMMERCIAL PRODUCTS DIVISION

P.O. Box 93 Ottawa, Canada

For more information, turn to Data Service card, circle No. 7

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John G. Meitner has joined Hughes Aircraft Co. as head of the analysis and research section of the launchers and power plants department of the company's guided missile laboratories. Meitner was previously head of research and later head of chemistry at Atlantic Research Corp.

The Department of the Army Meritorious Civilian Service Award was recently presented to **Harold C. Weber**, professor of chemical engineering at MIT, for his outstanding contributions to the Chemical Corps while serving as chairman of the Chemical Corps Advisory Council since March 1955.

Enoch R. Needles has been re-elected president of Engineers Joint Council (EJC) for 1959. At the same time, **Augustus B. Kinzel**, vice-president for research, Union Carbide, was elected vice-president of EJC.

Croll-Reynolds Co. announces election of **David H. Jackson** (left) as president. Jackson succeeds **Phillip E. Reynolds** who, with **Samuel W. Croll**, founded the company in 1917, and who recently retired as president. Other new officers at Croll-Reynolds are **Samuel W. Croll, Jr.**, as vice-president and treasurer, and **James T. Reynolds** as vice-president and secretary.

Newly-appointed executive secretary of the Engineering Manpower Commission is **L. K. Wheelock**. Wheelock replaces **W. T. Cavanaugh**, who resigned the position last December. He will continue in his post as assistant secretary of Engineers Joint Council.

NECROLOGY

Jerome Alexander, 82, consulting chemical engineer and chemist. A founding member of A.I.Ch.E., Alexander was the last surviving member with continuous membership since the founding. A specialist in colloid chemistry, and the author of several standard books on the subject, Alexander was decorated in 1931 by the French Government for his services to science and in 1936 was made a Chevalier of the Legion of Honor. In 1917, he helped to found the New York Section of the Societe de Chimie Industrielle. He was a fellow of the American Association for the Advancement of Science and a member of many other scientific groups.

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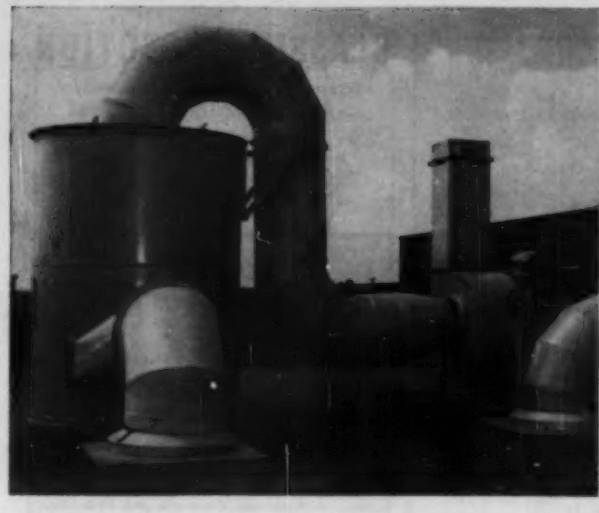

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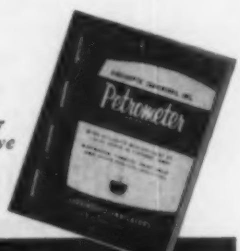

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CLASSIFIED SECTION

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CHEMICAL ENGINEERING TEACHING POSITIONS AVAILABLE

A list of chemical engineering teaching positions in schools and universities in the United States and Canada on Feb. 20, 1959 may be obtained from the Secretary, A.I.Ch.E., 25 West 45th Street, New York. Salary data and rank of position are given.

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ACADEMIC POSITION—September 1959. Assistant Professor of Chemical Engineering. Permanent position for young man with doctorate in Chemical Engineering, teach undergraduate subjects. Excellent facilities, new building, growing department. Minimum salary $6,000 for nine month contract. Teaching or industrial experience desirable. Write: A. N. Smith, Chemical and Metallurgical Engineering Department, San Jose State College, San Jose, California.

CHEMICAL ENGINEER—Graduate Chemical Engineer wanted for heading Process Engineering Department with old established Los Angeles processing equipment manufacturer. Experience in drying, dewatering or heat transfer desirable. Exceptional opportunity with a leading, expanding manufacturer. Box 23-2.

SITUATIONS WANTED

A.I.Ch.E. Members

TECHNICAL-EXECUTIVE—Chemical Engineer with proven ability in science management; research, operations, commercial development. Broad product line experience provides versatility. Depth of technical background enables direction and evaluation of performance of technical personnel. Highly qualified in economics and human relations. Box 4-2.

FOREIGN EMPLOYMENT for Chemical Engineer. Five years' experience R & D in petroleum, project engineering. Age 30, veteran, graduate degree, fluent French. Interested refinery or applications in European area. Box 5-2.

CHEMICAL ENGINEER—B.S.Ch.E.; graduate study. Patents granted and pending: U. S., Canada, U. K., Australia. Age 36, excellent health. Research—eight years as engineer and group leader, polyethylene, nylon intermediates, chlorination, formaldehyde, elastomers. Production—five years, polyethylene, gas synthesis and compression, alcohol synthesis, acrylics. Design—one year. Location unimportant, foreign welcomed. Salary commensurate with location and job. Presently employed. Box 6-2.

CHEMICAL ENGINEER—D.Ch.E., age 46, family. Over twenty years research, development and management in thermoplastics and synthetic organics. Last four years assistant to Technical Director. Desire management position with progressive organization. Box 8-2.

CHEMICAL ENGINEER—B.Sc.Ch.E., age 46. Seventeen years' experience research and development, process, project, and sales engineer for petroleum refineries and petrochemical plants. Foreign languages: perfect German, some Dutch and Russian. Now on consultant engineering assignment in Germany. Seek representation or position in Europe with engineering firm. Box 9-2.

B.S.-Ch.E. 1951 plus graduate credits in business. Eight years' experience in R & D—organic chemicals, polymerization, synthetic fibers. Currently supervisor of process and product development group. Desire position as head of research and development. Box 10-2.

CHEMICAL ENGINEER—B.S. 1941, age 38. Ten years' experience in aerosol industry; research and development, production, maintenance, engineering and plant management. Previous in drug and cosmetic field and unit operations. Desire position in production, management or research and development. Box 7-2.

CHEMICAL ENGINEERING EXECUTIVE — Former Plant Engineer, Director of Engineering, Staff of Executive, Research V.P.'s, large chemical company. Versatile, broad background, M.S.Ch.E. Age 39. Prefer New York-Philadelphia area, others considered. Present salary $12,000. Box 11-2.

CHEMICAL ENGINEER—B.Ch.E., age 27, married. Experience in process design. Seeking position with opportunity in plant technical or production. East Coast or Midwest preferred. Box 12-2.

COMMERCIAL DEVELOPMENT or other technical-economic position desired. Age 34. B.S.Ch.E. (M.I.T.); M.B.A. (N.Y.U.). Further graduate study in marketing, economics, and industrial engineering. Commercial development, market research, and production management experience. Box 13-2.

CHEMICAL ENGINEER—B.S., 1956, family, military service completed. Two years' experience in dust collection research, one year in silicone polymer development. Desire position leading to production in pilot plant or development laboratory. Location open, midwest preferred. Box 14-2.

CHEMICAL-MATHEMATICAL ENGINEER—age 37, single. Eleven years' experience. B.S. '43, Ch.E. '48 Columbia. Statistical experimental design; evolutionary operation; inventory, production and quality control; operations analysis and research for chemical company. New York City or metropolitan area. Present earnings $10,000. Box 15-2.

CHEMICAL ENGINEER — B.S.Ch.E. Thirteen years' supervisory experience in process development and production of pharmaceuticals, inorganics, organics and specialties. Seek responsible position in process engineering with chemical manufacturer. Prefer New Jersey or other eastern location. Box 16-2.

ACADEMIC POSITION in chemical engineering for Sept. 1959, D.Sc. (1957) 33, married, family. Seven years' varied industrial experience, research, production and process design. Sigma Xi. Location open. Box 17-2.

CHEMICAL ENGINEER — age 38. Thirteen years' experience supervising pilot and semi-works development of petrochemical and petroleum processes. Desire production opportunity in progressive company. Prefer central or southern east coast. Box 18-2.

TECHNICAL DIRECTOR—seek broader scope research, development, plant technical service or assistant to president or vice-president. Offer rich industrial experience. Cost improvement. Diversification. Petro-chemicals. U. S. or Latin America. Box 19-2.

PRODUCTION MANAGEMENT—age 31. Ten years' experience in process design and development, operations liaison and operations management in petrochemical industry. Three years departmental supervisor in production, including start-up operations. Desire responsible production position. Location immaterial. Box 20-2.

CHEMICAL ENGINEER — B.S. 1949 — M.S. 1950. Ten years' experience vegetable oil, petroleum, electronics, and explosives industries. Experienced as process engineer and senior supervisor. Desire position as project manager or superintendent. Would consider sales and/or position leading to part ownership. Box 22-2.

CHEMICAL ENGINEER—Ph.D., age 33, family. Eight years' diversified experience in process and product development, pilot plant design, construction, operation. Three years teaching. Desire creative position, R & D, or academic. Present salary $11,000. Box 23-2.

CHEMICAL ENGINEER—B.S. Diversified experience in research and development, college teaching, plant operation, and industrial engineering. Four years' experience in pilot plant operation and supervision. Desire responsible position. Box 24-2.

NON-MEMBER

CHEMICAL ENGINEER — Seventeen years' broad experience in petroleum, chemicals, plastics. Three commercial products in last five years. Seeking position in engineering, development or plant supervision. Box 21-2.

ADVANCE INFORMATION

The Situations Wanted portion of this Classified Section is preprinted and mailed a few days in advance of publication, to Employment Directors. Send names of individuals who should be on mailing list to: Miss E. Adelhardt, Chemical Engineering Progress, 25 W. 45th Street, New York 36, New York.

ADDITIONAL RECRUITEMENT ADVERTISEMENTS

See additional display advertisements on pages 9, 136 and 143.

CLASSIFIED SECTION RATES

Advertisements in the Classified Section are payable in advance at 24¢ a word, with a minimum of four lines accepted. Box number counts as two words. Advertisements average about six words a line. Members of the American Institute of Chemical Engineers in good standing are allowed one six-line Situation Wanted insertion (about 36 words) free of charge a year. Members may enter more than one insertion at half rates. Prospective employers and employees in using the Classified Section agree that all communications will be acknowledged; the service is made available on that condition. Answers to advertisements should be addressed to the box number, Classified Section, Chemical Engineering Progress, 25 West 45th Street, New York 36, N. Y. Telephone COlumbus 5-7330. Advertisements for this section should be in the editorial offices the 10th of the month preceding publication.

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Walter L. Badger, 72, Dow Chemical. Badger was noted particularly for his work in developing processes for desalting of sea water.

Donald G. Rogers, 66, former president of the National Aniline Division, Allied Chemical.

William R. Veazey, 75, director of Dow Chemical (retired).

Arthur W. Barry, 45, senior supervisor, Research and Development Division, Poly-chemicals Dept., Du Pont, Wilmington, Del.

Rudolph L. Hasche, 62, president, Hasche Engineering Co.

William S. Brackett, 60, vice-president engineering, Union Carbide Chemicals Co.

Charles S. Redding, 75, chairman of board of directors and former president of Leeds & Northrup Co., Philadelphia, Pa.

Walter M. Schwartz, 81, honorary chairman of board of Proctor & Schwartz, Inc., Philadelphia, Pa.

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A. I. Ch. E. candidates

The following is a list of candidates for the designated grades of membership in A.I.Ch.E. recommended for election by the Committee on Admissions. These names are listed in accordance with Article III, Section 8 of the Constitution of A.I.Ch.E.
candidates from Members and Associate Mem-
Objections to the election of any of these bers will receive careful consideration if received before March 15, 1959, at the office of the Secretary, A.I.Ch.E., 25 West 45th Street New York 36, N. Y.

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Airgood, James M., *Pittsburgh, Pa.*
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Borup, Marvin W., *Aiken, S. C.*
Brady, John J., *New York, N. Y.*
Dorsey, Clark L., Jr., *Seaford, Del.*
Hladky, John W., *New York, N. Y.*
Horlacher, W. R., Jr., *St. Louis, Mo.*
Keller, Frank, *Brooklyn, N. Y.*
Larraza, Pascual, *Tlalnepantla, Mexico*
Lawrence, Edward A., *Port Washington, N. Y.*
Leong, Frederic H. W., *Winchester, Mass.*
Lichtenwalner, Hart K., *Waterford, N. Y.*
Liphart, Charles R., *Poland, Ohio*
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Stavenger, Paul Lewis, *Stamford, Conn.*
Thalheimer, Robert C., *Wilmington, Del.*
Turner, Andrew, *South Charleston, W. Va.*
Vornkahl, Henry L., *Port Arthur, Tex.*

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news and notes of A.I.Ch.E.

Letter Symbols—From Mexico John Tatum Cox, professor at the University of Guadalajara, writes that the A.I.Ch.E.'s letter symbols for chemical engineering have been translated into Spanish; they are being supplied to all the chemical engineering classes at the university and are being dressed up for publication in a Spanish-language technical journal.

Monuments to Engineers—A drive is under way to bring more recognition to engineers. Ernest Hartford, one of the Assistant Secretaries of the American Society of Mechanical Engineers, is fostering "Monuments to Prominent Engineers." The suggestion has been made that a hall of fame be embodied in the new Engineering Center, and the 1959 edition of the *World Almanac* will have a full listing of the engineering awards. If any ideas on the subject strike our members, Mr. Hartford can be reached at the Engineering Societies Building, 29 West 39 St., New York 18, N. Y.

Our nominations for the Engineering Hall of Fame are the Campaign Chairmen of sections that have gone over the top in the member-gift drive. With fifteen now over the top, the chemical engineers are credited with 82% of their quota; however the last 18% will be the hardest to get. The chemicals' drive shows signs now of slowing down although this may be due partially to the recent holiday season. If you have not been approached by a Local Section solicitor and have not made a contribution, don't hang back—you still have two years in which to write off your pledge.

Membership Committee—Minutes of the meeting held in Cincinnati show that this committee is preparing a membership manual for its members and has made many suggestions on how the processing of applications can be speeded. The committee is trying to organize for 1959, and this is a plea to all retiring membership representatives in Local Sections and to all chairmen to make certain that they have forwarded appointees' names to E. M. Jones, the Membership Chairman, at Monsanto in Texas City, Texas.

Meeting registration fees — Council last year took a long look at meeting costs and decided that for the 1959 year the registration fees would increase $1 for Members, Associates, and Affiliates and $2 for nonmembers. All other categories remain the same.

Computer Programs — All members should be alerted to the computer-program interchange announced in *Chemical Engineering Progress* last month, pages 86 and 88. Approved by Council in December, this is an important program, and we recommend that everyone acquainted with computers and every company that uses them consider seriously full and adequate participation in the project. The interchange of technical knowledge is one of the characteristics that has strengthened the chemical engineering profession in the past, and this program is merely an extension of the normal procedures in the education of professional men.

New Local Sections—At the December Council meeting the Longview, Washington, Chemical Engineers' Club petitioned for Local Section status, which was granted, and the section will hereafter be known as the Southwest Washington Section.

Annual Report—In last month's News and Notes we failed to give credit where credit was due. Professor W. R. Marshall, Jr., of the University of Wisconsin was the author of the 1958 Annual Report. The assignment was given him early in 1958 by Council, and he collected and kept notes all year long on Institute activities. Incidentally, the philosophy behind the Annual Report is not to outline what happened in a particular year so much as it is to report to the membership on an annual basis significant developments in the profession. Sometimes an event is the culmination of a series of actions on the part of many committees over several years, and these annual reports will review for the membership the importance of such activities as they occur or as they affect the profession. The report, presented at the annual business meeting, will be sent to anyone requesting it.

F.J.V.A.

DORR-OLIVER designed, engineered and supplied all equipment for this 600-ton/day triple superphosphate plant of American Cyanamid Company at Brewster, Fla. Phosphoric acid is produced in the reactor tanks at right of open-air building. Premixers, reactors, small tank and sump in foreground are all equipped with LIGHTNIN Mixers.

What helped this Cyanamid plant exceed design capacity *in less than three months?*

200,000 tons a year of triple superphosphate fertilizer—that's the record-breaking production at this American Cyanamid Company plant.

Designed, engineered and equipped by Dorr-Oliver Incorporated, the plant reached its design capacity and guaranteed yields less than three months after initial startup.

How did they do it?

One part of the answer is good mixing. Three of the major operations—reaction, evaporation, water reclamation—employ LIGHTNIN Mixers.

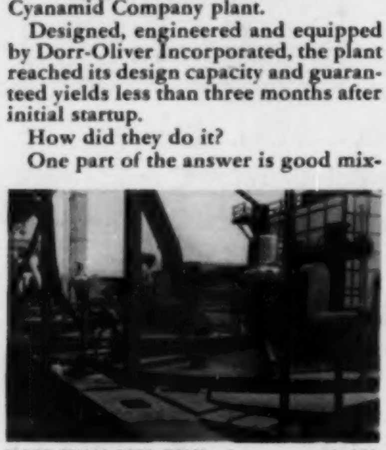
Optimum reactor yield

Every day, over 700 tons of phosphate rock and 600 tons of 98% sulfuric acid flow into the plant's two big premixers and four reactors. One 30-horsepower and five 60-horsepower turbine-type LIGHTNIN Mixers provide the intense but controlled agitation necessary to obtain maximum yields of 32% P_2O_5 phosphoric acid and coarse, uniform, fast-filtering gypsum.

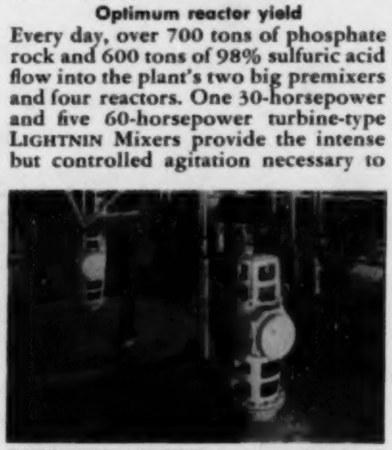
In the three-stage vacuum evaporator system, turbine-type LIGHTNINS keep the three seed tanks uniformly mixed.

Contaminated water at 3200 GPM is neutralized in two LIGHTNIN-equipped tanks, clarified in a 90-foot diameter Dorr Clarifier, cooled and reused, while acid wastes are neutralized in two other LIGHTNIN-mixed tanks prior to discharge.

"Good mixing" is the reason why Dorr-Oliver purchased LIGHTNIN Mixers throughout this record-toppling plant—and why LIGHTNINS are used in many plants designed by this experienced firm.



MORE THAN 1000 TONS of gypsum and 650 tons of 32% P_2O_5 phosphoric acid a day are handled by one 30-HP and five 60-HP LIGHTNINs, largest mixers ever used for this purpose.



TURBINE-TYPE LIGHTNINs in the seed tanks of American Cyanamid's vacuum evaporator station concentrate phosphoric acid from 32% to 54% P_2O_5.

What this can mean to you

How important is good mixing in *your* process? For mixers that can help you get a new plant onstream faster . . . give you *guaranteed* answers to mixing problems . . . and trim fluid mixing costs to a minimum—see your LIGHTNIN Mixer representative. He's listed in Chemical Engineering Catalog. Or write us direct.

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